National Aeronautics and
Space Administration

October 14, 1997

NRA-97-HEDS-01

RESEARCH ANNOUNCEMENT

Microgravity Combustion Science: Research and Flight Experiment Opportunities

Letters of Intent Due: .... December 1, 1997
Proposals Due: .... January 16, 1998

OMB Approval No. 2700-0042

MICROGRAVITY COMBUSTION SCIENCE: RESEARCH AND FLIGHT EXPERIMENT OPPORTUNITIES

NASA Research Announcement
Soliciting Research Proposals
for the Period Ending
January 16, 1998

NRA-97-HEDS-01
Issued: October 14, 1997

Office of Life and Microgravity Sciences and Applications
Human Exploration and Development of Space (HEDS) Enterprise
National Aeronautics and Space Administration
Washington, DC 20546-0001

NASA RESEARCH ANNOUNCEMENT
MICROGRAVITY COMBUSTION SCIENCE:
RESEARCH AND FLIGHT EXPERIMENT OPPORTUNITIES

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NASA RESEARCH ANNOUNCEMENT

MICROGRAVITY COMBUSTION SCIENCE: RESEARCH AND FLIGHT EXPERIMENT OPPORTUNITIES

This NASA Research Announcement (NRA) solicits proposals for flight experiments and for ground-based experimental and theoretical microgravity research in combustion science. The combustion science discipline represents a broad range of research areas including but not limited to gaseous flames (premixed and non-premixed); droplet, particle, spray, and dust flames; ignition and flamespread over liquid and solid fuel surfaces; smoldering combustion; and combustion synthesis. Further descriptions of the microgravity combustion science research activities and interests are given in Appendix A.

Investigations selected for flight experiment definition must successfully complete a number of subsequent development steps, including internal NASA and external peer review of the flight experiment, in order to be considered for a flight assignment. NASA does not guarantee that any investigation selected for definition will advance to flight experiment status. Investigations selected for support as ground-based research under the Microgravity Research Division (MRD) Research and Analysis (R&A) Program generally must propose again to a future solicitation in order to be selected for a flight opportunity.

Participation is open to U.S. and foreign investigators and to all categories of organizations: industry, educational institutions, other nonprofit organizations, NASA centers, and other U.S. Government agencies. **Though NASA welcomes proposals from non-U.S. investigators, NASA does not fund principal investigators at non-U.S. institutions.** (See Appendix A, Page 20). Proposals may be submitted at any time during the period ending January 16, 1998. (Late proposals will be considered if it is in the best interest of the Government.) Proposals will be evaluated by science peer reviews and engineering feasibility reviews. It is planned for selections to be announced by August 1998.

Appendices A and B provide technical and program information applicable only to this NRA. Appendix C contains general guidelines for the preparation of proposals solicited by an NRA.

This Announcement will not comprise the only invitation to submit a proposal to NASA for access to the reduced-gravity environment and is part of a planned sequence of solicitations inviting proposals in the various disciplines of the microgravity program.

NASA Research Announcement Identifier:	**NRA-97-HEDS-01**
NRA Release Date:	**October 14, 1997**
Letters of Intent Due:	**December 1, 1997**
Proposals Due:	**January 16, 1998**

This NRA is available electronically from and Letters of Intent may be submitted electronically via the Microgravity Research Division Web Page at:

http://microgravity.msad.hq.nasa.gov/

Alternatively, Letters of Intent may be submitted via e-mail to **loi@hq.nasa.gov**
If electronic means are not available, you may mail Letters of Intent to the address given below.

Proposals are to be submitted to the following address:

Dr. Merrill K. King
c/o Information Dynamics Inc.
Subject: NASA Research Proposal (NRA-97-HEDS-01)
300 D Street SW, Suite 801
Washington, DC 20024
Telephone for delivery services: (202) 479-2609

NASA cannot receive proposals on Saturdays, Sundays, or federal holidays.

Proposal copies required: 15

Proposers will receive a postcard confirming receipt of proposal within 10 working days of the due date.

Obtain Programmatic Information about this NRA from:

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Selecting Official:

Director
Microgravity Research Division
Office of Life and Microgravity Sciences and Applications
NASA Headquarters

Your interest and cooperation in participating in this effort are appreciated.

Arnauld E. Nicogossian, M.D.
Associate Administrator
Life and Microgravity Sciences and Applications

APPENDIX A
NRA-97-HEDS-01

TECHNICAL DESCRIPTION

MICROGRAVITY COMBUSTION SCIENCE: RESEARCH AND FLIGHT EXPERIMENT OPPORTUNITIES

I. INTRODUCTION

A. BACKGROUND

The Human Exploration and Development of Space (HEDS) Enterprise, one of four National Aeronautics and Space Administration (NASA) strategic enterprises, conducts a program of basic and applied research using the reduced-gravity environment to improve the understanding of fundamental physical, chemical, and biological processes. The scope of the program, sponsored by the Microgravity Research Division (MRD), ranges from applied research into the effects of low-gravity on the processing of various materials, to basic research that uses low-gravity to create test conditions to probe the fundamental behavior of matter. This announcement is part of an ongoing effort to develop research in a single specific scientific discipline, Microgravity Combustion Science. The Division last released a NASA Research Announcement (NRA) for Microgravity Combustion Science in 1995 and expects to continue to release NRAs in this discipline approximately every two years.

NASA has supported research in Microgravity Combustion Science for over two decades. An extensive research program supports theoretical and experimental investigations in ground-based laboratories. Additionally, many investigations are conducted using combustion research apparatus built to take advantage of the limited low-gravity test times available in ground-based facilities such as the drop towers at NASA Lewis Research Center or NASA's Parabolic Low-gravity Flight research aircraft. These ground-based experiments, along with theoretical modeling, form the basis for most of our current understanding of the effects of gravity on combustion processes and phenomena.

In the MRD program, ground-based research has been used to gain a preliminary understanding of phenomena and to define experiments to be conducted in the extended low-gravity test times available in spacecraft in low-Earth orbit. The MRD is developing multiple instruments for conduct of combustion research offering improved control and diagnostic capabilities relative to earlier experiments. These instruments are configured to investigate phenomena such as gaseous flames (premixed and diffusion), individual droplet and particle combustion, flame propagation in sprays and dusts, flame spread across solid and liquid surfaces, smoldering combustion, and combustion synthesis of novel materials. The MRD also anticipates limited near-term flight opportunities for investigations capable of making use of existing hardware where minor or no modifications would be required.

The MRD is also preparing for flight opportunities using International Space Station research instruments, including development of modular research instruments that can be configured (or reconfigured) to accommodate multiple experiments and multiple users. This is envisioned as an evolutionary program with the objectives of providing experimental data in response to increasingly sophisticated science requirements and of permitting the evolution of experimental approaches and technologies as needed for scientific investigations throughout the era of the International Space Station. This announcement is being released as part of a coordinated series of discipline-directed solicitations intended to span the range of the MRD program. Other MRD-supported solicitations planned for periodic release over the next several years encompass the areas of biotechnology, fluid physics, fundamental physics, and materials science.

B. RESEARCH ANNOUNCEMENT OBJECTIVES

The combustion science program seeks a coordinated research effort involving both space- and ground-based research. Ground-based research forms the foundation of this program, providing the necessary experimental and theoretical framework for development of rigorous understanding of basic combustion phenomena. This research can eventually mature to the point where it becomes the focus of a well-defined flight experiment. This NRA has the objective of broadening and enhancing the MRD microgravity combustion science program through the solicitation of:

1. Experimental studies which require the space environment to test clearly posed hypotheses, using existing or slightly modified instruments in space-based experiments to increase the understanding of combustion

2. Experiment concepts which will define and utilize new instruments for space-based experiments in combustion science

3. Ground-based theoretical and experimental studies which will lead to the definition or enhance the understanding of existing or potential flight experiments in combustion science, with emphasis on research leading to technologies required by future human space missions.

Further programmatic objectives of this NRA include objectives broadly emphasized by the civil space program, including the advancement of economically significant technologies, technology infusion into the private sector, and enhancement of the diversity of participation in the space program, along with several objectives of specific importance to the Microgravity Research program. These latter objectives include the support of investigators in early stages of their careers, with the purpose of developing a community of established researchers for the International Space Station and other missions in the next 10 to 20 years, and the pursuit of microgravity research that shows promise of contributing to economically significant advances in technology.

In support of the HEDS Enterprise goal to “enrich life on Earth through people living and working in Space,” individuals participating in the MRD Program are encouraged to help foster the development of a scientifically informed and aware public. The MRD Program represents an opportunity for NASA to enhance and broaden the public’s understanding and appreciation of the value of research in the microgravity environment of space. Therefore, all participants in this NRA are strongly encouraged to promote general scientific literacy and public understanding of the microgravity environment and microgravity combustion science through formal and/or informal education opportunities. Where appropriate, supported investigators will be required to produce, in collaboration with NASA, a plan for communicating to the public the value and importance of their work.

C. DESCRIPTION OF THE ANNOUNCEMENT

With this NRA, NASA is soliciting proposals to conduct research in microgravity combustion science, including experimental efforts sufficiently mature to justify near-term flight development. The goals of the discipline, along with several research areas of interest, are described in Section II. Proposals describing innovative low-gravity combustion science research beyond that described in Section II are also sought.

NASA is currently developing several types of flight instruments for microgravity combustion science research. Brief descriptions of the planned capabilities are given in Appendix B. NASA anticipates future flight opportunities for investigations with requirements which can be met by existing apparatus with only minor modifications. Successful proposals for use of the existing apparatus will be funded for advanced definition studies which will produce a detailed Science Requirements Document (SRD). Authorization to proceed into flight development is contingent upon successful peer review of the experiment and SRD by both science and engineering panels. NASA does not guarantee that any experiment selected for definition which plans to use existing hardware will advance to flight experiment status.

NASA also encourages submission of experimental proposals for which none of the existing flight instruments is appropriate. NASA anticipates the development of new combustion science research experiment apparatus and diagnostic tools for the International Space Station. Descriptions of possible future capabilities can also be found in Appendix B. These hardware descriptions are included as examples to allow researchers to consider the type of capabilities under development that might meet their science requirements. Though researchers should not feel limited by these capabilities, it must be emphasized that experiments calling for equipment significantly outside of these envelopes will involve considerably more expense to NASA, a factor which must be taken into consideration in funding decisions. Selected proposals requiring development of new capabilities (both currently planned ones and ones outside of the envelope), will be funded for flight-definition studies to define flight experiment parameters and conditions and the appropriate flight hardware. The length of the definition phase will be based on the experiment requirements, but will normally range from 6 to 24 months and will culminate in the preparation of an SRD.

Authorization to proceed into flight development is contingent upon successful peer review of the SRD by both science and engineering panels. NASA does not guarantee that any experiment selected for flight-definition which requires new instrument development will advance to flight experiment status. Investigations which do not proceed into flight development will normally be required to submit a proposal for continuation of support at the conclusion of a typical four-year period of funding.

Promising proposals which are not mature enough to allow development of a flight concept within two years of definition may be selected for support in the MRD Research and Analysis (R&A) Program. Investigations selected into the R&A program must generally propose again to a future announcement in order to be selected for a flight opportunity.

II. MICROGRAVITY COMBUSTION SCIENCE RESEARCH

A. PROGRAM SCOPE

Combustion is a key element of many critical technologies used by contemporary society. For example, electric power production, home heating, surface and air transportation, space propulsion, and materials synthesis all utilize combustion as a source of energy. Yet, although combustion technology is vital to our standard of living, it poses great challenges to maintaining a habitable environment. For example, pollutants, atmospheric change and global warming, unwanted fires and explosions, and the incineration of hazardous wastes are major problem areas which would benefit from improved understanding of combustion. Listed below are a number of scientific and technological questions of major current interest in the combustion community.

How can a quantitative predictive understanding of turbulent combustion, with its inherent interactions of multiple disparate temporal and spatial scales, be developed?

What are the gas-reaction, pyrolysis, and devolatilization kinetics for various hydrocarbon-fuel/oxidizer combinations, and how can they be predicted or extrapolated? What controls soot formation, agglomeration, and oxidation in combustion processes?

What mechanisms control flammability limits, and what controls detonations and instabilities?

How can the influences of a variety of transport phenomena on combustion, including thermophoresis, preferential diffusion, and electrical or magnetic field effects, be understood and quantified?

What factors control material ignitability, smolder, flame spread, and extinction? How do smolder waves transition to flames? How do flames propagate and fires grow? How can they be inhibited?

How do chemical kinetics and fluid dynamics couple? What occurs in and controls boundary-layer interactions, acoustic-reaction feedbacks, and development of coherent structures in flames?

How can we make continued progress toward controlling generation and emission of pollutants from combustion processes in a cost-effective manner?

How can we modify fossil fuel combustion systems to make greater use of alternative fuels while maintaining or even improving efficiency, pollutant control, safety, and reliability?

How can fire and explosion control processes provide improved protection without contributing to destruction of high-altitude ozone?

How can combustion technology effect risk reduction and enable safe, economical destruction of hazardous wastes?

How can we utilize combustion processes to synthesize useful types and amounts of high-value materials such as fullerenes, carbon black, silica, and ceramic/metallic composite materials?

How can we improve combustion technologies for advanced ground, air, and space propulsion systems?

Effects of gravitational forces impede combustion studies more than most other areas of scientific study, since combustion involves production of high-temperature gases whose low density results in buoyant motion, vastly complicating the execution and interpretation of experiments. Effects of buoyancy are so ubiquitous that their enormous negative impact on the rational development of combustion science is generally not recognized. Buoyant motion also triggers the onset of turbulence, yielding complicating unsteady effects. Finally, gravity forces cause particles and droplets to settle, inhibiting deconvoluted studies of heterogeneous flames important to furnace, incineration, and power generation technologies. Thus, effects of buoyancy have seriously limited our capabilities to carry out “clean” experiments needed for fundamental understanding of flame phenomena. Combustion scientists can use microgravity to simplify the study of many combustion processes, allowing fresh insights into important problems via a deeper understanding of elemental phenomena also found in Earth-based combustion processes and to provide valuable information concerning how fires behave in microgravity and how fire safety on spacecraft can be enhanced. Several topic areas in the field of combustion which have been the subject of recent microgravity research emphasis include:

Turbulence and Combustion. Virtually all practical combustion devices involve turbulent flows; the wide range of turbulence length and time scales present generally precludes exact numerical simulation and also presents a significant challenge to experimental investigations. Microgravity uniquely limits the range of length and time scales to those large enough to be tractable experimentally and more readily simulated. Preliminary microgravity experiments reveal that buoyancy plays a role in the turbulence characteristics in regimes where it had been previously assumed that the flow field and flame behavior were independent of gravitational influence. One particularly powerful approach for treating the coupling between fluid motion and combustion chemistry, based on studies of laminar flames, is currently under development. This approach, referred to as laminar flamelet theory, shows promise as a tractable representation of turbulent combustion. The extension of laminar flamelet theories to predict fully turbulent flames cannot presently be exploited, however, due to limitations of our current knowledge base caused by the buoyancy-induced interferences occurring during laminar flame studies. Microgravity combustion studies provide an opportunity to eliminate these interferences and, thus, markedly advance our capability to address turbulent combustion phenomena.

Transient Processes in Gaseous Flames. Numerous types of instabilities are possible in combustion of flowing gases, some being gravity-dependent and others being gravity-independent. Such phenomena as ignition, extinction, and unsteady response of flames to externally imposed perturbations (e.g., pressure oscillations) are of major importance as regards fire safety, production of pollutants, and combustion efficiency. Research studies in a microgravity environment provide for examination of fundamental phenomena involved in these transient phenomena without the confounding effects of buoyancy-induced flows which will, under normal gravity conditions, also respond in an unsteady manner to such imposed perturbations, often masking fundamental phenomena of interest. With understanding of these phenomena, strategies for controlling ignition, extinction, and responses of flames to externally imposed perturbations in practical combustion devices can better be devised.

Soot Processes. Soot is a critical element in many combustion systems, strongly affecting combustor lifetime, efficiency, peak power output, and pollution generation. The short time scales and small spatial volumes affecting soot formation and destruction processes under normal gravity conditions preclude experimental probing. Furthermore, buoyancy accelerates, in an uncontrolled fashion, the flow field in which soot is formed and oxidized; this also inhibits scientific investigations. Microgravity offers a unique opportunity for controlling the flow environment and through this control extending the range of germane experimental conditions which can be studied. The lack of buoyantly induced, accelerated flow results in longer residence times for primary soot formation, clustering, cluster-cluster agglomeration, and oxidation in a variety of flames. In addition, soot particle pathlines are strongly altered under microgravity conditions, resulting in major changes in the environmental history seen by the soot precursors and particles. From the perspective of practical benefit, the fundamental understanding of the processes controlling soot formation, aggregation, and oxidation is of vital importance, since such understanding would allow us to develop methods to predict and control sooting associated with combustion processes under a wide variety of circumstances.

Measurement (Species, Velocity, Temperature) Technology. A historic (and valid) criticism of microgravity experimental research is lack of quantification of meaningful variables (e.g., species concentrations). Advancement in understanding of chemical kinetic mechanisms is inhibited by an inability to measure progress of reactions and to quantify the detailed temperature and flow fields in which those reactions take place. Improved measurement methods in both 1g and microgravity are a growing focus of terrestrial research. Technological improvements in measurement capabilities will lead directly to improved kinetic and flow-field modeling leading to an enhanced capability for design of combustors with reduced pollutant generation and improved fuel efficiency. Spin-offs of these technologies can and are being used not only in laboratories distant from the inventor's own, but also in the monitoring of pollutant emissions from various sources. In the future, these technologies will be used to evaluate fuel consumption, product generation, heat transfer efficiency, and pollutant control in manufacturing processes, and to serve as *in-situ* engine performance and emission levels monitors. The resulting combination of diagnostic sensors and computational algorithms will allow electronic controls to play a larger part in practical combustion systems, enabling so-called "intelligent combustors."

Droplet/Particle Combustion at High Pressures. Microgravity is of particular benefit in studies of particle and liquid droplet ignition and combustion in that it permits elimination of settling effects and of buoyancy-induced flows around the droplets, thus leading to truly symmetrical (and hence one-dimensional) geometry and allowing droplets to be restrained within the field of view of various diagnostics. Currently, high-pressure (including the supercritical regime) operation of combustion devices is being examined for increased efficiency. Unfortunately, pollutant (e.g., soot and oxides of nitrogen) generation increases with increasing pressure; hence, military and NASA aeropropulsion research is heavily populated with studies aimed at realization of the theoretical efficiency improvements with simultaneous minimization of pollutants. Another application of this technology is in the area of hazardous waste disposal; supercritical water oxidation of hazardous wastes has been predicted as an important technology of the future, hopefully yielding only benign products (carbon dioxide and water). Much of our detailed knowledge in the area of combustion of droplets and particles has been obtained at low pressure; extension of studies to high pressure is required. For example, soot studies have mostly been performed near ambient pressures with flame temperatures of less than 2000K; diesel engines operate at over 50 atmospheres at 2800K. Much of our knowledge of soot kinetics may not be applicable to these high-temperature, high-pressure regimes. High-pressure operation is accompanied by increased buoyant flow effects; microgravity experiments will enable, as in other situations, an isolation of the effects of the buoyancy on flame structure, flammability limits, and flame speeds.

Classical Model Validation/Benchmark Data. Combustion textbooks are replete with theories which are incompletely tested though widely accepted (through historical precedent). These theories often neglect buoyancy effects and assume simplified transport processes. Moreover, one-dimensional behavior is often assumed in situations where buoyant effects preclude such one-dimensionality. Microgravity continues to offer the unique ability to test, via ideal truly one-dimensional experiments, the accuracy of specific aspects of theories and to provide a benchmark data base against which extensions to existing theories and altogether new theories can be tested.

Flame Structure and Elementary Mechanisms. A fruitful approach to achieving meaningful technology gains in combustion processes must be centered on development of better understanding of the fundamentals of the unit processes involved. Without such an understanding, approaches taken to improving combustion devices tend to involve incremental trial-and-error perturbations around current state-of-the-art designs, with opportunities to achieve possible major improvements with radically different approaches being missed. However, if one fully understands the physics and chemistry involved in a given combustion process, including detailed understanding of the unit subprocesses and how they interact, this understanding can be combined into physically accurate models which can then be used for parametric exploration of new combustion domains via computer simulation, with possible definition of radically different approaches to accomplishment of various combustion goals. Accordingly, emphasis needs to be placed on studies of combustion fundamentals which are not currently well understood; gravitational effects associated with normal Earth-bound combustion studies have prevented study of many elementary processes which tend to be overshadowed by gravitation-induced processes such as buoyancy or settling.

Direct Numerical Simulation. Although DNS is being widely pursued for definition of detailed features of the flame structure and transport processes (and their interactions) associated with combustion, due to the large range of length and time scales, direct numerical simulation of practical or even idealized devices is considered to be, at best, a technology of the future. DNS modeling to date has, however, shown the need to account for preferential mass diffusion even in turbulent flame environments. Microgravity experiments again lessen the range of scales and may make problems tractable at least for model validation of laboratory-scale experiments, a first step toward DNS validation. DNS is expected to ultimately play a major role in the design of practical combustion systems and obviate the need for the expensive construction and modification of a wide range of breadboards, prototypes, and experimental models of combustion devices; it may also be used for optimization of design elements, subsystems, controls, and overall system performance at reduced cost and time.

Spray and Aerosol Combustion. Realistic sprays include a liquid breakup region, dispersed multiphase flow, turbulent mixing processes, and various levels of flame interactions throughout the spray. Idealization of spray configurations in a quiescent environment (the starting point for models) has been impossible in 1g due to settling of large droplets and buoyant pluming of post-combustion gases. Microgravity offers the promise of such idealization but has just begun to provide experimental data on ignition, fire spread, and interactions in idealized linear and planar arrays of monosized droplets. Spray and aerosol cloud combustion accounts for 25% of the world's energy use yet remains poorly understood from both a fundamental and practical perspective. Improved understanding of the flammability and flame interactions of sprays can be expected to yield improved combustion efficiency in practical devices, but this will only occur with an improved detailed theoretical description. In the area of combustion safety, dust clouds contribute to accidental fires and explosions (grain elevators, underground mines). Finally, improved spray technology can be applied to improvements in hazardous waste incineration.

Combustion Synthesis. The use of flames to synthesize materials is expanding rapidly. Products include valuable vapors (e.g., acetylene), ultrafine particles (fullerenes, silicon oxides, titanium oxides), coatings (diamonds) or monolithic solids (boron carbide, titanium boride). Fullerene production is being investigated extensively, but the product yields of fullerenes are currently typically less than 1%, leaving tremendous potential for improvement. Sedimentation and buoyant plumes yielding limited critical residence times again interfere with present investigations into both the scientific mechanisms of material production and the quality of the actual industrial product. For example, pressure and buoyancy effects on soot-filled flames are not understood sufficiently to determine the ideal operating conditions to maximize fullerene generation in either premixed or diffusion flames. Microgravity offers the promise of isolating the effects of pressure by removing the influence of buoyancy on the material production process. A major difficulty in self-propagating, high-temperature synthesis (SHS) of materials is the control of porosity and the microstructure of the products. SHS reactions generating gaseous, liquid, or combined phases are prone to gravity-induced fluid flows, leading to non-uniform microstructure and undesirable properties of the product material due to segregation and density gradient effects. Gravitational forces have been shown to play a dominant role in controlling both the combustion-synthesis reactions and the morphologies of the synthesis products. Current research is geared towards interpreting the differences between normal- and low-gravity processing.

Partial Gravity Studies. The utilization of partial gravity environments enables systematic scientific testing of effects of this parameter on fundamental processes as well as tying directly to the nation's desire for space exploration. Both the Moon and Mars are in NASA's future; microgravity and normal gravity studies have already shown that combustion processes are distinctly affected by reductions in gravity, with a conclusion that the partial gravitational levels on the Moon and Mars may yield increased flammability. In addition, partial gravity environments may have strong effects on *in-situ* propellant production processes as well as on utilization of these products.

Surface Flame Spread. Anyone who has observed the combustion of solid fuels, particularly flame spread across and burning of vertical walls, is well aware of the dominant effects of buoyancy on such processes under normal gravity conditions, a dominance which makes understanding of other phenomena involved very difficult (an example of how buoyancy can "mask" such phenomena). Accordingly, microgravity studies of flame spread across solid fuels and liquid pools are of considerable interest from a fundamental point of view as well as being very important in terms of fire safety on various space platforms. On Earth, the fluid mechanics of large-scale fires are complicated by buoyancy-fed turbulent processes and thermal radiation interactions with surrounding materials, terrain, and building structure. Current models are still somewhat primitive, with little elucidation of the role of thermal radiation in almost any aspect of fires. Investigations of large-scale fires under microgravity conditions have yet to begin, but it has been shown that radiation takes on heightened importance in small-scale fires in microgravity, indicating that results from laboratory-scale experiments in microgravity might be utilized in modeling of large-scale fires. In terms of NASA's own direct interests, ongoing investigations of material flammability and fire behavior in microgravity have yielded vital guidance to improved fire safety aboard orbiting spacecraft. There does remain, however, a need for normal-gravity versus microgravity correlations of ignition, flame spread, flammability, and extinction conditions.

The research categories listed above are not meant to be all-inclusive; proposals which do not fall into any of these areas are encouraged. In the future, as further discussed later in this Appendix, the Microgravity Research Division also plans to support fundamental research and enabling technologies associated with space studies, recognizing the need of supporting a vigorous theoretical and experimental ground-based program which supports space research and from which new ideas for space research can grow.

Studies of combustion phenomena, particularly in terms of opportunities for combustion research in space, can be considered according to their fundamental science and to anticipated consequences of greatly diminished gravitational effects. Much research in microgravity combustion science can be discussed within this conceptual structure: (1) how gravity, when eliminated or greatly reduced, results in elucidating effects otherwise masked, (2) the role of gravity as an additional independent parameter in model validation, and (3) how combustion systems perform in extraterrestrial environments.

B. CURRENT PROGRAM OVERVIEW

As stated in NASA's Microgravity Research Program Strategic Management Handbook, the Microgravity Research Program mission is "to use the microgravity environment of space as a tool to advance knowledge; to use space as a laboratory to explore the nature of physical phenomena, contributing to progress in science and technology on Earth; and to study the role of gravity in technological processes, building a scientific foundation for understanding the consequences of gravitational environments beyond Earth's boundaries." For accomplishment of this mission, both a ground-based program and a flight-experiments program are employed; in addition, development of facilities, diagnostic tools, and experiment modules for conduct of multiple experiments is supported. The ground-based program has two major objectives: (1) nurturing and development of ideas and concepts that may be later developed into flight experiments and (2) providing theoretical and experimental underpinnings to support understanding of phenomena being studied in a microgravity environment. Ground-based investigations include theoretical and experimental laboratory research, drop-tower tests, and parabolic aircraft flight experiments. In the flight program, experiments judged to justify use of the flight environment are developed and executed. These experiments are conducted in microgravity environments provided by suborbital sounding rockets, the Space Shuttle mid-deck or isolated cargo bay support structures, the

Shuttle-based Spacelab or Spacehab pressurized laboratory facilities, the Russian Mir station, International Space Station facilities, and other available carriers.

Currently, as a result of previous NASA Research Announcements in the combustion area, the Microgravity Combustion Science program is supporting 48 ground-based studies, 7 flight-definition studies, 8 flight programs, and 3 Glovebox investigations. These studies can be divided into seven major categories: premixed gas flames; gaseous diffusion flames; combustion of individual fuel droplets, clusters of droplets, and sprays; combustion of individual solid particles and dust clouds; flame spread across liquid and solid fuel surfaces; smoldering combustion; and combustion synthesis.

As indicated above, the term “combustion” encompasses a wide range of processes; major subcategories of combustion of interest to scientific researchers and of practical importance are briefly described below, with inclusion of comments on the importance of gravitational forces in these processes and on how this drives our microgravity combustion program. One important point to note at the outset is that combustion processes involve closely coupled complex chemical kinetic and physical transport phenomena; study at different gravity levels offers a novel tool for changing the relative importance of these effects, thus permitting “decoupling” of unit processes and separate study of each.

First is the area of “**premixed gas flames.**” In this mode of combustion, the fuel and oxidizer gases are completely mixed prior to application of an ignition stimulus (for example, an electrical spark). Subsequent to input of a sufficient amount of such stimulus energy (definition of the minimum energy required is itself of considerable practical and scientific interest), a reaction front (flame) propagates away from the ignition source into the reactive mixture. Also of major interest is the velocity at which this flame moves through the unreacted premixed gases (the flame speed) as a function of the type of fuel and oxidizer and of their ratio in the mixture. (Indeed, for sufficiently high or low ratios of fuel to oxidizer in the mixture, the flame will <u>not</u> propagate into the mixture after removal of the ignition stimulus; the nature and quantitative values of these “flammability limits” are both of scientific interest and great practical importance in terms of fire safety concerns.)

In this area of premixed gas flames, gravity can strongly affect such parameters as flame speed, flammability limits, flame shape, flame stability, and energy requirements for ignition of various fuel/oxidizer mixtures, chiefly through the effects of buoyancy. The products of the combustion process are much hotter than the initial mixture and consequently much less dense; in the presence of gravity, this density difference results in buoyancy forces which cause the products to flow upward relative to the ingredients, thus strongly influencing the transfer of heat from the products to the unreacted ingredients, a major driver of the flame propagation, and, in some cases, leading to major changes in the structure of the flame. In the absence of gravity, such forces disappear, allowing study of fundamental processes which are overshadowed by buoyancy-driven flows in a normal gravity field. Moreover, the absence of gravity permits study of truly spherically symmetric flame propagation away from a point ignition source, which is not possible in a normal 1g field where the unidirectional buoyancy-induced flow destroys such spherical symmetry; this is of tremendous benefit in permitting comparison of experimental data to fundamental models, which are much more straightforward in a truly one-dimensional geometry. In this area, NASA is currently supporting experimental and modeling studies of the effects of gravity on flammability limits, flame stability/extinction, flame structure and shape, and sooting. In particular, we are funding studies of the effects of radiative heat losses on premixed flames in microgravity environments where such effects dominate flammability limits and near-limit flame structure/behavior. Modeling activities being supported include both simplified analytical approaches aimed at elucidating mechanisms and detailed numerical analysis aimed at quantifying them. In addition, we are funding microgravity studies of low-flow premixed turbulent flames (which cannot be studied in normal gravity environments due to strong buoyancy-induced flows). From these and future studies, we hope to resolve effects of buoyant convection on flammability limits and define mechanisms which control flammability limits and contribute to flame stability and shape, with a final output being increased understanding of fundamental flame properties and rigorous testing of theoretical models, both important to improvements in combustor design and fire/explosion avoidance. To date, several discoveries, possible only via microgravity experiments, have been made in this area; these include self-extinguishing flames, flameballs, flame cylinders, and dilution-enhanced flammability, which is all important in hazard control and basic combustion science.

A second category of combustion of major interest is that of **gaseous diffusion flames**; there are many subcategories of such flames (laminar or turbulent; coflowing fuel and oxidizer streams, one ingredient jetting into a stagnant volume of the other, or impinging opposed jets of fuel and oxidizer, for example). In all cases, unless the flow velocities involved are quite high, gravity can strongly affect the flame structure and even the ultimate products of combustion, again via the mechanism of buoyancy-driven flows resulting from density differences of reactants and products in non-zero gravity fields. For example, in the case of an upward jet of fuel penetrating into a quiescent oxidizer (e.g., air), buoyancy in a normal-gravity field will result in enhanced upward flow of the products which in turn will result in entrainment of oxidizer into the fuel jet; such entrainment will be absent at zero gravity. Since so many practical applications utilize diffusion flames of various types, we are concentrating a large fraction of our support in this area. Activities being supported include study of the effects of diffusion-flame structure (quite different in normal gravity and microgravity) on soot formation in diffusion flames; effects of altered relationships between chemical kinetic time scales and flow time scales accompanying change from a normal gravity environment to a microgravity environment on such parameters as flammability limits and burning rates; and the effects of buoyancy on the structure of gas-jet diffusion flames in laminar, transition, and turbulent flow regimes. In particular, chemical kinetics and species and heat transport tend to be closely coupled in diffusion flames, leading to difficulty in separating and thus quantifying their individual contributions; use of microgravity experiments provides a means of altering the balance between these processes, thus permitting isolation of the individual mechanisms. Within this combustion subcategory, the first data on turbulent and transition gas-jet flames in microgravity have recently been obtained, offering potential toward development of understanding and prediction of turbulent combustion phenomena, which is of widespread practical interest. In addition, phenomenological data on soot production in microgravity flames are being obtained for use in developing soot kinetics models, with eventual potential application to development of effective strategies for control of soot formation in practical burners. These studies are expected to have a significant impact on understanding and predictive capabilities as regards diffusion flames, ultimately leading to approaches for achieving significant reduction of pollution and increased energy conversion efficiencies in such flames.

Combustion of liquid fuel droplets in an oxidizing gas such as air is also of great practical importance; better understanding of fundamental processes involved should lead to more efficient combustor designs for the many applications in which liquid fuels are utilized. The presence of gravity greatly hinders fundamental studies of droplet combustion due to flows induced by both the sinking of the high density droplets in the surrounding gas and the buoyancy-induced acceleration of hot combustion products upwards relative to the surrounding gas; these phenomena result in asymmetrical burning with not only non-zero but very non-uniform gas flows around the droplet. In the absence of gravity, these flows disappear, permitting study of a very clean simple burning configuration for extraction of vitally needed phenomenological combustion information. In this area, we are supporting fundamental studies of microgravity combustion of single-component and multicomponent, truly spherical (not obtainable in normal gravity environments) droplets. In addition, we are supporting studies of the combustion of ordered arrays of fuel droplets in a microgravity environment (again not possible under normal gravity conditions), of droplet clusters, and of sprays produced by an electrostatic dispersion process, for development of understanding of the interactions of combustion of individual droplets in spray combustion (used in many practical combustors). To date, several new phenomena related to droplet combustion have been revealed in drop-tower microgravity testing. From these studies, we plan to develop a greatly improved understanding of spray combustion processes, leading to major improvements in design of combustors utilizing liquid fuels.

Another combustion area of major importance, particularly in terms of fire safety, **is flame propagation in fuel-dust clouds** (coal-dust clouds leading to mine explosions, grain-dust clouds leading to explosion of silos/grain elevators). It is particularly difficult to study ignition and combustion characteristics of such clouds under normal gravity conditions due to the tendency of an initially well-dispersed dust cloud to quickly settle in such a field as a result of the differences between density of the particles and the gas, leading to coalescence of particles which collide during this settling process, and to non-uniform air/fuel ratios within the cloud. Accordingly, microgravity provides essentially the only means of studying the fundamentals of dust cloud ignition, combustion, and explosion, and of quantifying information about conditions where ignition/combustion will occur. Microgravity experiments showing "chattering flame propagation" in freely suspended fuel particle clouds have led to theoretical developments regarding flame-acoustic interactions which apply to triggering of acoustic instabilities in practical gas turbines. At this time, in support of this area, we are funding a study of the detailed mechanisms of ignition and combustion of individual solid particles, a study of combustion of porous solid fuel particles, a study of interactions of burning metal particles, and a study of the structure and dynamics of reacting dusty flows.

Flame spread along surfaces, solid or liquid, is another important category of combustion, involving reaction between a gaseous oxidizer (e.g., air) and condensed-phase fuel. This area is particularly relevant to fire safety. In quiescent surroundings or with a gentle flow of the oxidizer across the fuel surface (either in the same direction or opposed to the flamespread direction), this process is quite sensitive to gravity level, again due to buoyant flow effects associated with the hot combustion products in normal gravity environments (with buoyancy effects in both liquid and gas phases playing roles in the case of flame spread across liquids). Hence, material flammability test results under normal gravity conditions do not agree with results observed under microgravity conditions, and microgravity testing is thus necessary for understanding of flamespread mechanisms in reduced or zero-g environments as well as for determining materials fire safety characteristics for spacecraft applications. Currently, we are supporting several experimental and analytical studies of the spread of flames across solid and liquid fuel surfaces, both in quiescent oxidizer environments and with low-velocity flows both in the same direction and opposed to the flame spread direction. The immediate goals of these activities are to develop better understanding of what controls ignitability of solid or liquid fuels in various oxidizer environments, what physical processes control flamespread, how flames propagate and grow, what inhibits burning of solid fuels, and what conditions lead to extinction. Obvious benefits from development of better understanding of the fundamental processes controlling flamespread over solid or liquid fuels lie mainly in the area of fire safety.

Another combustion process of importance with regard to fire safety is **smoldering combustion**, a relatively slow non-flaming exothermic oxidation process involving a gaseous oxidizer and a porous solid fuel, well exemplified by the combustion of a cigarette. Since this is a process in which heat is generated slowly and is thus quite sensitive to heat exchange within the surroundings, buoyancy effects associated with product and reactant gas density differences in a gravitational field are of major importance; accordingly, smoldering combustion is expected to be quite different in the presence or absence of gravity. At this time, we are supporting two programs in this area, one mainly an experimental study of the mechanisms of smoldering combustion in polyurethane foam and the other an analytical modeling effort of smoldering in general. The long times required for experiments of this nature require flight experiments for definition of how microgravity influences smoldering combustion; these experiments are being used in conjunction with ongoing ground-based normal-gravity experiments for the development of better understanding of the fundamental mechanisms of smoldering combustion, which should have a significant impact on prevention of unwanted fires both on the ground and in space.

An area of combustion which has only recently begun receiving major attention is the **combustion synthesis of materials**; one subcategory of particular interest is generally referred to as self-propagating high-temperature synthesis (SHS) processing. In SHS processing, a packed bed of two (or more) powders, where at least one has oxidation potential and another is a fuel, is ignited at one end, with subsequent spread of a reaction front through the material producing a new material product (generally rather porous) via solid-solid and/or liquid-solid exothermic reactions. The product generally consists of a mixture of metals, metal oxides, metal carbides, metal nitrides, and/or intermetallic compounds. As one might expect, gravity fields can have considerable impact on this process, both through buoyancy-induced flow effects on heat transport processes and through gravity-driven flow of liquid-phase intermediates through a porous solid matrix prior to cooldown/freezing of the liquid phases behind the reaction front. Since the composition and particularly the crystal morphology of the final product (which strongly affects its properties) tend to be very sensitive to the temperature-time history seen during the passing of the SHS combustion wave, these gravity-dependent effects can have major effects on the product produced. At this time, we are supporting a study in which an exothermic combustion reaction is being used to produce a porous ceramic-ceramic matrix which is infiltrated with the excess reactant metal. A major goal of this study is definition of fundamental mechanistic differences between how this combustion synthesis reaction behaves under normal and low-gravity conditions, with the ultimate aim of defining approaches to tailoring combustion synthesis processes for production of materials with optimized properties for various end uses. Also in the area of combustion synthesis, we have recently initiated funding of a study of the effects of gravity on combustion synthesis of fullerenes and another study on production of metal and ceramic nanoparticles.

Although the majority of the current programs are ground-based studies centered on analytical modeling activities, testing in drop towers and parabolic aircraft at NASA Lewis Research Center, and testing at the Japan Microgravity Center (JAMIC) dropshaft in Hokkaido, Japan, limited flight testing has also been carried out on Sounding Rockets and on the Space Shuttle. Three Sounding Rocket tests on the Spread Across Liquids (SAL) Program have been successfully completed to date. Each flight provided approximately six minutes of microgravity time (during which three burns were accomplished) for investigation of the flame spread characteristics across a deep pool of liquid fuel in a microgravity environment, with particle imaging velocimetry, rainbow schlieren, and flamespread data being obtained for comparison with model predictions. This program has recently been approved for five additional flights. In addition, three Sounding Rocket flights have been carried out on a study of flame spread along solid fuel surfaces titled "Diffusive and Radiative Transport in Fires Experiment (DARTFire)."

Eight shuttle (middeck) experiments have been completed to date on the Solid Surface Combustion Experiment (SSCE), with samples of PMMA being burnt in various oxygen-nitrogen atmospheres under quiescent conditions. Two additional shuttle flights have been approved for this experiment; it is expected that these will be completed during 1997 or 1998. Two Getaway Special Canister (GASCAN) payload shuttle flight tests on the Microgravity Smoldering Combustion experiment (MSC) have also been recently completed, and five additional flight tests have been approved. Three major combustion experiments were recently flown on the Microgravity Space Laboratory (MSL-1) on the Space Shuttle; these experiments are the Droplet Combustion Experiment (DCE), the Study of Flameballs at Low Lewis Numbers experiment (SOFBALL), and the Laminar Soot Processes in Flames experiment (LSP). In addition, the Turbulent Gas Jet Diffusion Flame (TGDF) experiment is tentatively scheduled to go to flight in late 1997.

To date, four Microgravity Combustion Glovebox Experiments, one on USML-2 (October 1995) and three on USMP-3 (February 1996), have been carried out; these were the Fiber-Supported Droplet Combustion (FSDC) experiment, the Forced Flow Flame-Spreading Test (FFFT), the Comparative Soot Diagnostics (CSD) experiment, and the Radiative Ignition and Transition to Flame Spread Investigation (RITSI). In addition, a repeat of the FSDC experiment was flown on MSL-1, with two additional glovebox experiments, Opposed-Flow Flame Spread on Cylindrical Surfaces (OFFS) and Enclosed Laminar Flames (ELF), planned for the near future. Finally, additional FFFT tests and Candle Flame Combustion tests were carried out in the Mir Glovebox facility during 1996.

To date, our work in the microgravity combustion arena has demonstrated major differences in structures of various types of flames under microgravity versus normal gravity environments. For example, significant differences in the sooting characteristics of diffusion flames, of major interest for pollutant control in practical combustion devices, have been observed under these two limiting gravity conditions. In addition, major differences between the ignition and flamespreading characteristics of liquids and solids (e.g., plastics, wood, foams, pools of liquid fuel) in microgravity and normal gravity, of major importance with regard to fire safety concerns, have been revealed. Besides the practical implications to combustion efficiency (energy conservation), pollutant control (environmental considerations), and flammability (fire safety), these studies have established that better mechanistic understanding of individual processes making up the overall combustion process can be obtained by comparing of results from microgravity and normal gravity tests, with potential for major redesign of combustion processes and hardware to yield higher efficiency, reduced pollutant production, and increased fire safety on Earth as well as in space.

C. ENTERPRISE FOR HUMAN EXPLORATION AND DEVELOPMENT OF SPACE (HEDS)

In early 1994, as part of ongoing reorganization at NASA, the agency established six major enterprises, later reduced to four. In the current organization, the Microgravity Research Division of the Office of Life and Microgravity Sciences and Applications (OLMSA) has become part of the Human Exploration and Development of Space (HEDS) Enterprise. In January, 1996, a Strategic Plan for HEDS was put into place, and development of "roadmaps" for the future directions of activities within HEDS was initiated. The three major charges of the HEDS activities are (1) to advance and communicate scientific knowledge and understanding of the Earth, the solar system, the universe, and the environment of space for research, (2) to explore, use, and enable the development of space for human enterprise, and (3) to research, develop, verify, and transfer advanced aeronautics, space, and related technologies.

The HEDS Enterprise has as a major goal contributing significantly to the opening of the space frontier and expanding the human experience into the far reaches of space. The focus of the MRD program in the HEDS Strategic Enterprise is to foster fundamental understanding of physical and chemical processes, building a foundation of knowledge that can be applied to Earth- and space-based technologies. Specifically, understanding of the fundamental role of gravity in the space environment in these processes is needed to achieve breakthroughs in science and to develop enabling technology for exploration and colonization of space. The need for improved understanding of combustion phenomena to enable future space technologies and operations should be recognized as one of the primary opportunities of the discipline. Included are development of spacecraft combustion/propulsion systems, fire safety, use of *in-situ* resources, and power generation in extraterrestrial environments. Many of the combustion or other chemical conversion process principles involved are relevant to several technology areas simultaneously.

A rapidly developing area of particular relevance to exploration of other bodies in the solar system is *In Situ* Resource Utilization (ISRU). Due to the cost constraints associated with carrying all of the necessary resources for a sustained visit and return trip from either the Moon or Mars, utilization of natural resources at the landing site is receiving strong consideration. Basic physical and chemical methods will be applied to process local resources into usable commodities. The focus of activities of the research community must be to develop an understanding of operation of these processes in a non-Earth environment. Proposals are encouraged on efforts to advance the current understanding of unit operations in a low-gravity environment with the goal of improved process design and development. Examples of local resource utilization-related processes include chemical reaction engineering for production of fuels and/or oxidizers, combustion of such products in a reduced-gravity environment, and fire safety during such operations. Lunar regolith (soil) contains significant amounts of oxygen, chemically bound in various minerals, which will require processing to produce oxygen for use in propulsion and life support systems. Similarly, it is believed that Martian soil contains significant amounts of water which can be electrolyzed into oxygen and hydrogen, again for propellants and life support. Utilizing the Martian atmosphere for the production of oxygen, carbon monoxide, and methane for propellants is also possible. In all of these scenarios, a fundamental understanding of the chemical conversion processes involved is vital.

At a recent (August 5-7, 1997) HEDS Technology Workshop, several fire research areas of interest with respect to a manned Mars mission were defined. These included:

1. Development of earlier, more sensitive fire detection systems for use under microgravity and Mars-gravity (0.38g) scenarios

2. Extended studies of the flammability of thick fuels and of degradation of polymers at microgravity and Mars gravity at various oxygen mole fractions and radiant heat flux loadings.

3. Study of combustor performance and fire safety for premixed methane/oxygen systems at 0.38g

4. Experimental and modeling studies of extinguishment by dilution with various agents under microgravity and 0.38g conditions

5. Study of potential fire safety problems involved with various *In-situ* resource utilization scenarios.

While basic research into fundamentals is still considered to be of major importance to our program, there is obviously a major shift of emphasis toward “mission-oriented” research, that is, research aimed at specific problems in combustion applications on Earth as well as under reduced-gravity or microgravity conditions. Thus, it is important that firmer links between the research being done using microgravity and applications to practical applications on Earth (e.g., increased efficiency of conversion of chemical energy contained in fuels to useful work, reduction of combustion-generated pollutants from automobile engines and other combustors, decreased fire and explosion hazards) need to be established for an increasing percentage of efforts funded under this program.

Included among the long-term goals of the HEDS microgravity combustion program are (1) melding microgravity combustion space experiments together with ground-based combustion studies, using gravity as an added independent variable, to provide better understanding of the physical and chemical mechanisms involved in combustion and to provide more rigorous testing of analytical models, (2) utilizing basic research to provide technological advances in various combustion processes/devices (e.g., internal combustion engines, turbines, combustion synthesis, incinerators), (3) creating the understanding that will permit lessons learned in microgravity combustion experiments and modeling to be used in optimizing combustion devices on Earth, (4) providing quantum leaps in the areas of fire safety and minimization of combustion-generated pollution, (5) providing the understanding which will permit efficient use of present and alternative fuels, which will be increasingly needed as we deplete our oil and gas reserves, and (6) developing a better understanding of various combustion synthesis processes, opening the door to production of novel tailored materials here on Earth as well as in space.

Potential combustion technologies which can be developed or enhanced for terrestrial and space exploration applications include the following:

1. Active control over thermal efficiency and pollutant generation through sensor development and miniaturization accompanied by development of algorithms relating sensor readings, control settings, and system performance

2. Use of magnetic and electric fields to improve thermal efficiency (microgravity enables improved isolation of and thus understanding of field effects on ions and paramagnetic molecules such as oxygen

3. Improved atomization methods for diesel and gas turbine engines, leading to improved fuel utilization, through improved understanding of fundamentals of liquid jet breakup and droplet interactions in sprays

4. Flame-zone pollution control in premixed and diffusion burners, reducing the need for post-combustion cleanup devices, through fundamentally improved understanding of flame structure and of mechanisms of formation of soot and oxides of nitrogen

5. Improved exhaust gas monitoring for cars and other combustion devices combined with development of “smart” controls to compensate for fuel variations and/or degradation of engine components to decrease pollution emissions

6. New flame-stabilization/control technologies for burners, enabling reliable, ultra-lean premixed combustion, through improved understanding of flame stabilization zones in engines, burners, etc.

7. Development of improved strategies and procedures for fire prevention, detection, and suppression in the microgravity environment associated with the Space Station and in the reduced gravity Lunar and Martian environments

8. Reduction of hazards associated with gaseous fuel combustion through better mapping and understanding of flammability limit and combustion instability phenomena

9. Development of improved protection against large-scale fires (house fires, forest fires) via better fundamental understanding of material ignition and flamespread phenomena

10. Reduction of mine and grain silo explosion hazards through the development of understanding of fundamentals associated with these phenomena

11. Improved reliability in hazardous liquid waste incineration, resulting from studies of droplet and spray burning and of pollution generation

12. Industrial-scale, combustion-generated fullerene production through determination of approaches for improving the yields of fullerenic material in flame systems;

13. Production of combustion-generated composite materials with improved strength, reliability, and ductility through better understanding of how to improve micro-structural uniformity and control porosity via gravitational control

14. Development of methods for producing and utilizing alternate fuel/oxidizer combinations associated with Lunar, Martian, or other extraterrestrial habitats.

As indicated earlier, while conduct of fundamental science investigations remains a cornerstone of the Microgravity Combustion Science program, more weight will be placed in the future on relevance to HEDS goals, with linkage of the proposed research to attainment of these goals receiving increased emphasis. Establishment of scaling laws with respect to gravitational effects on combustion processes and definition of where such laws break down due to changes in dominant physics are of interest. However, future proposals are <u>not</u> limited to the topic areas discussed in this Appendix; <u>extension to combustion topics not currently included in the Microgravity Combustion program is strongly encouraged</u> to permit us to broaden the program scope. It appears that the most fruitful approach to achieving meaningful technology gains in processes involving combustion is to concentrate on developing better understanding of the fundamentals of the individual processes involved. With such understanding, including definition of details of the unit processes and their interactions, physically accurate models which can be used for parametric exploration of new combustion domains via computer simulation can be developed, with potential resultant definition of radically different approaches to the accomplishment of various combustion goals. As discussed earlier, normal-gravity conditions have prevented study of many elementary processes which are overshadowed by processes such as buoyancy, making it difficult to develop mechanistic understanding of unit phenomena making up overall combustion processes. It cannot be emphasized too strongly that our program is dedicated to taking advantage of microgravity to untangle these complications, allowing major strides in our understanding of combustion processes and in subsequent development of improved combustion devices leading to improved quality of life on Earth.

III. EXPERIMENTAL APPARATUS AND FLIGHT OPPORTUNITIES

A. EXPERIMENTAL APPARATUS

In order to address aspects of the research described in Section II, a number of pieces of flight hardware are being developed by NASA. These are described in Appendix B. NASA also contemplates the development of new research capabilities for combustion experiments, also described in Appendix B. In addition, Appendix B lists the ground-based facilities that are available to support definition studies.

Limited early flight opportunities under this NRA will be on the Space Shuttle, on Sounding Rockets, or on the International Space Station. For the shuttle opportunities, the experimental hardware will be located in the middeck, allowing astronaut interaction, or in the cargo bay, which does not permit such interaction. Residual acceleration levels on the order of 10^{-4} g are available in the Shuttle for limited periods of time. The Space Acceleration Measurement System (SAMS) is expected to be available to measure and record actual accelerations at or near the apparatus for both Shuttle and ISS experiments. Flight duration’s range from 7 to 16 days. A high-capacity communications network supports Shuttle and payload operations. Downlink channels enable users to monitor their instrument status and science data streams in real time. An uplink channel enables them to act on that information. Considerable additional information on the Shuttle accommodations and capabilities can be found in the STS Investigators' Guide (see Bibliography). Experimental apparatus for the early utilization of the International Space Station will be primarily in facilities such as the Glovebox and Express Rack (ISS versions of Shuttle middeck class experiments) with the Combustion Integrated Rack (CIE) of the Fluids/Combustion Facility anticipated to be available in the 2001-2002 time period.

B. DIAGNOSTIC MEASUREMENTS

The capability to characterize science experiments in reduced gravity is essential to scientific progress in this program. NASA, in ground-based normal and reduced-gravity studies, is developing techniques for enhancing imaging and visualization and improving measurements of temperature, velocity, species, and particle-size distributions. As these techniques mature, those most required by investigators will be reviewed for space flight development as part of the future flight equipment capability.

C. FLIGHT OPPORTUNITIES

Missions available for this program include several Shuttle flights, Sounding Rocket flights, and missions on the International Space Station after 2001.

D. EXPERIMENT FLIGHT-DEFINITION AND FLIGHT ASSIGNMENT PROCESS

Ground-based research is usually necessary to clearly define flight experiment objectives. This research may involve experimentation in NASA-provided ground-based facilities, including those providing a limited duration low-gravity environment. (These facilities are described in Appendix B.) Successful proposals for flight opportunities will be supported for a ground-based definition phase before review for flight assignment. The amount of support (technical, scientific, and budgetary) and the definition period length (usually from 6 months to 24 months) will depend on the specific investigator's needs and the availability of resources from NASA. However, in preparing their budget plan for this research announcement, all respondents seeking funding for flight-definition should estimate their annual costs for four years.

Shortly after selection of projects for flight definition, NASA will meet with the Principal Investigators to identify fundamental technical feasibility issues. This process will help determine whether there are any outstanding issues that would inhibit the success of the flight project, considering both technical challenges and required resources. At that point, NASA may make a judgment as to whether a project will continue the flight-definition process or revert to the Ground-Based (Research and Analysis) Program (see below).

1. Near-Term Flight Opportunities. Successful proposals for use of the existing instruments will be funded for a period of advanced definition work, after which time the investigator will generate a detailed Science Requirements Document (SRD). The SRD, a detailed experiment description outlining the specific experiment parameters and conditions, as well as the background and justification for flight, must be prepared jointly by the Principal Investigator and a NASA-appointed Project Scientist and submitted for peer review. This formal review by both science and engineering panels will determine if space flight is required to meet the science objectives and if instrument capabilities can be provided to meet the science requirements. Following approval by the panels, subject to program resources, continuation support will be awarded and the hardware will be modified to meet the science requirements. NASA does not guarantee that any experiment selected for definition will advance to flight experiment status. Investigations with unresolved science or engineering issues at the review of the SRD may be placed in ground-based status with support of limited duration (normally from one to three years), and the investigator may be asked to submit a proposal to a subsequent solicitation for further support.

2. Future Flight Opportunities. Successful proposals for the development of new apparatus will be funded for a period of definition. The length of the definition period will be based on the experiment requirements, but will generally be from 6 to 24 months. At the end of the experiment definition phase, the investigator will generate a detailed SRD. Following successful peer review of the SRD by science

and engineering panels, the experiment will proceed into flight development and be considered for flight. As with opportunities for existing instruments, NASA does not guarantee that any experiment selected for definition will advance to flight development status, and the possibility exists that investigations may be placed in ground-based status, with continuing support from NASA for a limited period of time.

3. Ground-Based Definition Opportunities. Promising proposals for experimental research which are not mature enough to allow development of an SRD after two years of definition, and proposals for development of theory in areas of current or potential microgravity experiments, may be selected for support in the MRD Research and Analysis (R&A) Program. R&A studies are funded for periods of up to four years. A new proposal to a future announcement is required in order to be selected for a flight opportunity or to continue R&A studies if appropriate. Proposals for development of new technologies for flight experiments that will provide new opportunities for combustion science research are encouraged.

IV. UNDERGRADUATE STUDENT RESEARCH OPPORTUNITIES

Active research experience is one of the most effective techniques for attracting talented undergraduates to and retaining them in careers in mathematics, science, and engineering. The undergraduate years are critical in the educational sequence, as career-choice points and as the first real opportunities for in-depth study. MRD is endeavoring to foster the career development of undergraduate students by offering optional supplements of approximately $5,000 per student to approved research tasks for undergraduate student research projects. This supplement may be requested for each year of the proposed research. These projects should involve undergraduate students in a meaningful way in ongoing research programs or in related sub-projects specifically designed for this purpose.

The proposals for the undergraduate student research projects should include the nature of the student activities, presenting plans that will ensure the development of student-faculty and student-student interaction and communication; a concise description of the experience and record of the Principal Investigator and any potential advisors of students; and the criteria for evaluating the success of the project. Proposals for up to two students should constitute a separate section (see information on proposal formatting in Section V, Subsection B) of about two pages per student and will not be counted against the maximum page limit. This effort should be shown as a separate line in the budget summary for each year.

The review criteria to determine whether NASA will fund this activity if the proposal is selected are the following:

1. The value of the educational experience for the student participants, particularly the appropriateness of the research projects for and the nature of student participation in these activities

2. The quality of plans for student preparation, student mentoring, and follow through designed to promote continuation of student interest and involvement in research

3. The proposed arrangements for managing the project and how the project will be evaluated.

If selected for involvement in this program, investigators are required to submit reports on these activities in conjunction with reporting on the primary grant. In particular, reports should include information on the activities of each student, the degree of interaction with their mentors, the future career plans of the student (if known), and an evaluation of the project progress.

V. PROPOSAL SUBMISSION INFORMATION

This section delineates the requirements for submission of proposals in response to this announcement. The research project described in a proposal submitted under this announcement must be directed by a Principal Investigator who is responsible for all research activities and may include one or more Co-Investigators. Proposers must address all of the relevant selection criteria (described in Section IX) in their proposal and must format their proposal as described in this section. Additional general information for submission of proposals in response to NASA Research Announcements may be found in Appendix C.

A. LETTER OF INTENT

Organizations planning to submit a proposal in response to this NRA should notify NASA of their intent to propose by electronically sending a Letter of Intent (LOI) via the MRD Web Page:

http://microgravity.msad.hq.nasa.gov/

Alternatively, Letters of Intent may be submitted via e-mail to the following address: **loi@hq.nasa.gov**

If electronic means are not available, Letters of Intent may be mailed to the address given for proposal submission in the following section, or facsimile transmission is acceptable; the MRD fax number is (202) 358-3091.

The Letter of Intent, which should not exceed two pages in length, must be typewritten in English and include the following information:

1. The potential Principal Investigator (PI) name, position, organization, address, telephone, fax, and e-mail address
2. A list of potential Co-Investigators' names, positions, and organizations
3. General scientific/technical objectives of the research
4. Intent to participate in the Undergraduate Student Research Opportunities, if appropriate
5. The equipment listed in this NRA which is of interest, if appropriate.

The Letter of Intent should be received at NASA Headquarters no later than December 1, 1997. The Letter of Intent is being requested for informational and planning purposes only, and is not binding on the signatories; institutional authorizations are not required. The Letter of Intent allows NASA to better match expertise in the composition of peer review panels with the response from this solicitation. In the Letter of Intent, investigators may request more detail on the capabilities of the specific equipment (Appendix B) that might be used to accomplish their scientific objectives and/or items listed in the Bibliography (Appendix A, Section X).

B. PROPOSAL

The proposal should not exceed 20 pages in length, exclusive of appendices and supplementary material, and should be typed on 8-1/2 x 11 inch paper with a 10- or 12-point font. Extensive appendices and ring-bound proposals are discouraged. Reprints and preprints of relevant work will be forwarded to the reviewers if submitted as attachments to the proposal, with the understanding that the reviewer is not required to read them.

The guidance in Appendix C, Section D regarding the content of renewal proposals is not applicable to this NRA. Renewal proposals should not rely on references to previous proposals for any information required for a complete proposal. **It is particularly important that proposers submitting renewal proposals make clear to the reviewers what they have accomplished on their current effort and how it supports their request for additional sponsorship.**

Fifteen copies of the proposal must be received at NASA Headquarters by January 16, 1998, 4:30 PM EST to assure full consideration. Treatment of late proposals is described in Appendix C. Send proposals to the following address:

Dr. Merrill K. King
c/o Information Dynamics Inc.
Subject: NASA Research Proposal (NRA-97-HEDS-01)
300 D Street, SW, Suite 801
Washington, DC 20024
Telephone number for delivery services: (202) 479-2609

NASA can not receive deliveries on Saturdays, Sundays, or federal holidays.

Proposals submitted in response to this Announcement must be typewritten in English and contain at least the following elements (in addition to the required information given in Appendix C) in the format shown below:

1. Title Page
2. Table of Contents
3. Executive Summary (replaces abstract) (1-2 pages)
4. Research Project Description containing the following elements:
    - Statement of the hypothesis, objective, and value of this research
    - Review of relevant research
    - Justification of the need for low-gravity to meet the objectives of the experiment
    - Description of the diagnostic measurements that would be required to satisfy the scientific objectives of any proposed low-gravity experiments
    - Estimation of time profile of reduced-gravity levels needed for the experiment or series of experiments
    - A clear and unambiguous justification of the need to perform the experiment in space as opposed to ground-based reduced-gravity facilities (flight-definition proposals only)
    - A description of a ground-based testing program that might be needed to complete the definition of the space flight experiment requirements in terms of experiment conditions, acceleration levels and durations, control and diagnostic measurement requirements, etc.
5. Optional Undergraduate Student Research Opportunity (not counted in the 20 page limit)
6. Management plan appropriate for the scope and size of the proposed project, describing the roles and responsibilities of the participants
7. **Prior Period of Support**
    - **For proposals for renewal of ongoing MRD sponsored projects, a summary of the objective and accomplishments of the prior period of support, with presentation of justification for continued support**
8. Appendices:
    - Budget plan estimating annual costs for up to four years. There should be at least one page for each of the four years and one page summarizing the total four-year budget. The information desired is explained below
    - Summary of current and pending support for the Principal Investigator and Co-Investigators
    - Complete current curriculum vita for the Principal and Co-Investigators, listing education, publications, and other relevant information necessary to assess the experience and capabilities of the senior participants
    - Forms and Signed Certifications (see below)
9. 3.5 inch computer diskette containing electronic copy of Principal Investigator's name, address, complete project title, and executive summary.

The title page must clearly identify the research announcement to which the proposal is responding; the title of the proposed research, the Principal Investigator name, institution, address and telephone number; the total proposed cost and proposed duration; and all required signatures.

The executive summary should succinctly convey, in broad terms, what it is the proposer wants to do, how the proposer plans to do it, why it is important, how it meets the requirements for microgravity relevance, and how it relates to outlined HEDS objectives. The executive summary replaces the proposal abstract.

Each proposal should include the Solicited Proposal Application (Form A). Those requesting financial support should also include: Detailed Budget for 12-Month Period Direct Costs Only (Form B) for each year of funding; Budget for Entire Project Period Direct Costs Only (Form C); signed Certifications regarding Drug-Free Workplace Requirements (Form D); Debarment, Suspension, and other Responsibility Matters (Form E); and Lobbying (Form F). Copies of these forms may be found at the end of this document. **In addition, it is important that the proposer provide a realistic estimate of the demands which will be made on facilities at NASA Lewis Research Center during each year of the proposed effort; Form G is supplied for this purpose and should be carefully completed.**

Proposal Cost Detail Desired. Sufficient proposal cost detail and supporting information will facilitate a speedy evaluation and award. Dollar amounts proposed with no explanation (e.g., Equipment: $58,000, or Labor: $10,000) may cause delays in evaluation or award. The proposed costing information should be sufficiently detailed to allow the Government to identify cost elements for evaluation purposes. Generally, the Government will evaluate cost as to reasonableness, allowability, and allocability. Enclose explanatory information, as needed; each category should be explained. Offerors should exercise prudent judgment, as the amount of detail necessary varies with the complexity of the proposal. **The Proposers are strongly urged to be realistic as to the time-phasing of their funding requirements, rather than simply "straight-lining" the costs over four years. Very often, funds will be expended at a relatively low level during the first few months of a project, with higher than "straight-line" expenditures during the remaining grant period; if the proposer anticipates this being the case, he/she should indicate this in the proposed funding profile, since "carry-over" funding from year to year is strongly discouraged by NASA management.**

VI. NRA FUNDING

The total amount of funding for this program is subject to the annual NASA budget cycle. The Government's obligation to make awards is contingent upon the availability of appropriated funds from which payment for award purposes can be made and the receipt of proposals which the Government determines are acceptable for an award under this NRA.

For the purposes of budget planning, we have assumed that the Microgravity Research Division will fund 4 to 6 flight experiment definition proposals. These efforts are typically funded at an average of $175,000 per year. It is also anticipated that approximately 40 ground-based study proposals will be funded, at an average of approximately $100,000 per year, for up to 4 years. The initial fiscal year (FY) 1999 funding for all proposals will be adjusted, if required, to reflect partial fiscal year efforts. **It is particularly important that the proposer realistically forecast the projected spending timeline rather than merely assuming an equal amount (adjusted for inflation) of requirements for each year.** The proposed budget for ground-based studies should include researcher's salary, travel to science and NASA meetings (for a flight investigation, roughly eight meetings per year with NASA should be anticipated, though travel activity will vary over the development of the experiment), other expenses (publication costs, computing or workstation costs), burdens, and overhead. During subsequent years, NRAs similar to this NRA will be issued, and it is planned that funds will be available for additional investigations.

VII. GUIDELINES FOR INTERNATIONAL PARTICIPATION

NASA accepts proposals from all countries, although this program does not financially support Principal Investigators in countries other than the U.S. Accordingly, proposals from non-U.S. entities should not include a cost plan. Non-U.S. proposals and U.S. proposals which include non-U.S. participation, must be endorsed by the appropriate government agency in the country from which the non-U.S. participant is proposing. Such endorsement should indicate that:

1. The proposal merits careful consideration by NASA

2. If the proposal is selected, sufficient funds will be made available, from the country from which the non-U.S. participant is proposing, to undertake the activity as proposed.

Proposals, along with the requested number of copies and Letter of Endorsement, must be forwarded to NASA in time to arrive before the deadline established for this NRA.

All proposals must be typewritten in English. All non-U.S. proposals will undergo the same evaluation and selection process as those originating in the U.S.

Sponsoring non-U.S. agencies may, in exceptional situations, forward a proposal directly to the address given on Page iii of the first section of this announcement if review and endorsement is not possible before the announced closing date. In such cases, an accompanying letter should indicate when a decision on endorsement can be expected.

Successful and unsuccessful proposers will be notified by mail directly by the NASA program office coordinating the NRA. Copies of these letters will be sent to the sponsoring government agency. Should a non-U.S. proposal or U.S. proposal with non-U.S. participation be selected, NASA's Office of External Relations will arrange with the non-U.S. sponsoring agency for the proposed participation on a no-exchange-of-funds basis, in which NASA and the appropriate government agency will each bear the cost of discharging its respective responsibilities. Depending on the nature and extent of the proposed cooperation, these arrangements may entail:

1. A letter of notification by NASA

2. An exchange of letters between NASA and the sponsoring government agency

3. An agreement or memorandum of understanding between NASA and the sponsoring government agency.

VIII. NASA/NEDO COOPERATIVE ACTIVITIES

NASA has entered into an agreement with the New Energy and Industrial Technology Organization (NEDO) in Japan resulting in establishment of a Microgravity Combustion Coordination Group (MCCG) for identifying areas of potential cooperation related to combustion research in a microgravity environment in which each side might utilize facilities of the other side, primarily NASA's Lewis Research Center facilities and the dropshaft (10-second microgravity duration) of the Japanese Microgravity Center (JAMIC). Possible personnel exchanges and joint utilization of microgravity facilities of both sides for programs proposed jointly by Japanese and US investigators will be reviewed on a case-by-case basis by the MCCG subsequent to acceptance of the proposal via peer review in each country; any specific cooperative activities recommended by the MCCG will be implemented through individual agreements negotiated between NASA and NEDO. As regards this solicitation, US proposers may include such cooperative activity as part of their proposal. However, since participation by the Japanese investigators will depend on their being funded by their own sponsoring agencies via a separate review process, it is recommended that the proposal be structured so as to permit accomplishment of significant defined goals without the participation of the Japanese investigator(s). For further information or clarification, potential proposers should contact Dr. Merrill K. King at (202) 358-0817.

IX. EVALUATION AND SELECTION

A. EVALUATION PROCESS

The evaluation process for this NRA will begin with a scientific and technical external peer review of the submitted proposals. NASA will also conduct an internal engineering review of the potential hardware requirements for proposals that include flight experiments. The external peer review and internal engineering review panels will be coordinated by the NASA Enterprise Scientist for Combustion Science. Consideration of the programmatic objectives of this NRA, as discussed in the introduction to this Appendix, will be factored in by NASA to ensure enhancement of program breadth, balance, and diversity; NASA will also consider the cost of the proposal. The MRD Director will make the final selection based on science panel and programmatic recommendations. Upon completion of all deliberations, a selection statement will be released notifying each proposer of proposal selection or rejection. Offerers whose proposals are declined will have the opportunity of a verbal debriefing regarding the reasons for this decision. Additional information on the evaluation and selection process is given in Appendix C.

B. EVALUATION FACTORS

This section replaces Section I of Appendix C. The principal elements considered in the evaluation of proposals solicited by this NRA are: relevance to NASA's objectives, intrinsic merit, and cost. Of these, intrinsic merit has the greatest weight, followed by relevance to NASA's objectives, of slightly lesser weight. Both of these elements have greater weight than cost. Evaluation of the intrinsic merit of the proposal includes consideration of the following factors, in descending order of importance:

1. Overall scientific or technical merit, including evidence of unique or innovative methods, approaches, or concepts, and the potential for new discoveries or understanding, or delivery of new technologies/products

2. Qualifications, capabilities, and experience of the proposed Principal Investigator, team leader, or key personnel who are critical in achieving the proposal objectives

3. Institutional resources and experience that are critical in achieving the proposal objectives

4. Overall standing among similar proposals available for evaluation and/or evaluation against the known state-of-the-art.

Evaluation of the cost of a proposed effort includes consideration of the realism and reasonableness of the proposed cost, and the relationship of the proposed cost to available funds.

Responding to the following questions should be kept in mind by proposers:

1. Is microgravity of fundamental importance to the proposed study, either in terms of unmasking effects hidden under normal gravity conditions or in terms of using gravity level as an added independent parameter?

2. Do the issues addressed by the research have the potential to close major gaps in the understanding of fundamentals of combustion processes?

3. Is there potential for elucidation of previously unknown phenomena?

4. Is the project likely to have significant benefits/applications to ground-based as well as space-based operations involving combustion processes?

5. Are the results likely to be broadly useful, leading to further theoretical or experimental studies?

6. Can another project in the specific sub-area be justified in terms of limited resource allocation?

7. Is the project technologically feasible, without requirements for substantial new technological advances?

8. How will this project stimulate research and education in the combustion area?

9. How does the projected cost/benefit ratio compare with other projects competing for the same resources?

10. What is the potential of this project in terms of stimulating future technological "spin-offs"?

11. Are there strong, well-defined linkages between the research and HEDS goals? (See Section II of this Appendix).

C. SELECTION CATEGORIES, PERIOD OF SUPPORT, AND FLIGHT-DEFINITION PROCESS

Proposals selected for support through this NRA will be selected as either ground-based or flight-definition investigations. Investigators offered support in the ground-based program normally will be required to submit a new proposal for competitive renewal after no more than four years of support. Investigators offered flight-definition status are expected to begin preparing detailed experiment requirements and concepts for flight development shortly after selection in cooperation with the assigned representative from the Lewis Research Center. The selected investigations will be required to comply with MRD policies, including the return of all appropriate information for inclusion in the MRD archives during the performance of and at the completion of the contract or grant.

Commitment by NASA to proceed from flight-definition to the execution of a flight experiment will be made only after several additional engineering and scientific reviews and project milestones have established the feasibility and merit of the proposed experiment. Investigations that do not pass these reviews will be funded for a limited period (generally no more than four years from the initial award date) to allow an orderly termination of the project.

The Principal Investigator in flight-definition must prepare a Science Requirements Document (SRD) early in the development of a flight experiment to guide the design, engineering, and integration effort for the instrument. The SRD describes specific experiment parameters, conditions, background, and justification for flight. Ground-based, normal, and reduced-gravity experimentation, as well as any necessary parallel modeling efforts, may also be required to prepare an adequate SRD. The amount of support (technical, scientific, and budgetary) provided to investigators by NASA will be determined based upon specific investigator needs and the availability of resources to NASA and MRD.

It should be noted that while a proposer can propose multiple flights, in general NASA will not commit to more than one flight without a reflight review after the first flight.

X. BIBLIOGRAPHY

Background materials are available to NRA proposers upon written request to:

Mr. Stephen N. Simons
Mail Stop 500-115
Lewis Research Center
NASA
Cleveland, OH 44135
(216) 433-5277
stephen.n.simons@lerc.nasa.gov

Documents which may provide useful information to proposers are listed below:

Microgravity Science & Applications Program Tasks and Bibliography for FY1996. NASA Technical Memorandum 4780, March 1997.

Microgravity Combustion Science: Progress, Plans, and Opportunities, NASA Technical Memorandum 105410, April 1992.

Microgravity Combustion Science: 1995 Program Update, NASA Technical Memorandum 106858, April, 1995.

Proceedings of the Second International Microgravity Combustion Workshop, NASA Conference Publication 10113, September 15-17, 1992.

Proceedings of the Third International Microgravity Combustion Workshop, NASA Conference Publication 10174, April 11-13,1995.

Proceedings of the Fourth International Microgravity Combustion Workshop, NASA Conference Publication 10194, May 19-21, 1997.

STS Investigators' Guide, NASA Marshall Space Flight Center.

In addition, considerable information on Lewis Research Center facilities, experiments, educational activities, missions, and services are available on the Web at **http://zeta.lerc.nasa.gov**

APPENDIX B
NRA-97-HEDS-01

HARDWARE AND FACILITY DESCRIPTIONS

MICROGRAVITY COMBUSTION SCIENCE: RESEARCH AND FLIGHT EXPERIMENT OPPORTUNITIES

The Microgravity Research Division (MRD) is pursuing a program for the development of Space Shuttle and early International Space Station (ISS) payloads that can be configured (or reconfigured) to accommodate multiple users. This evolutionary program is expected to meet the science requirements of increasingly sophisticated microgravity investigations and to permit the eventual development of experiment payload technologies for research throughout the era of the ISS.

I. FLIGHT HARDWARE

The experimental apparatus described in this section are under development for flight on a series of Space Shuttle missions and/or ISS. NASA anticipates several additional future flight opportunities for investigations capable of using this hardware. Minor modifications of the current hardware may be possible to make it more versatile and to accommodate users and experiments other than those for which it was originally designed. Several potential enhancements are highlighted in the descriptions for the current hardware. Availability of the instruments described here, with or without modification, is contingent upon the availability and allocation of resources, and cannot be guaranteed at this time.

More detailed descriptions of the current flight hardware may be requested in the Letter of Intent described in Appendix A, Section V.

A. ISS COMBUSTION INTEGRATED RACK (CIR))

The International Space Station United States Laboratory Module will contain the Fluids and Combustion Facility (FCP). The FCF is a modular, multi-user, microgravity science facility which will occupy three powered payload instrumentation racks plus the equivalent volume of one unpowered stowage rack. Together the three racks will provide the fundamental physical and functional infrastructure necessary to perform combustion science, fluid physics, and adjunct science experiments on-board the International Space Station.

The Combustion Integrated Rack (CIR) will be the first FCF rack to be launched in year 2001. It will be equipped to operate as a single integrated rack to provide the initial set of Principal Investigators with the functionality required to perform their experiments. The CIR features a fold down optics plate, a combustion chamber, replaceable diagnostics, and an integrated gas mixing assembly.

Optics Bench Features:
- Folds down and slides out for full and easy access
- Diagnostics can be easily replaced and interchanged
- Gas mixing system is integrated with the Combustion Chamber Assembly

Optics Bench Specifications:
- Width x Length x Depth: 86.5 x 124.5 x 10 cm
- Tubing and Wiring internal to bench

Diagnostics Specifications:

- 6 locations, Replaceable on-orbit
- W x L x D: 23 cm x 50 cm x 25 cm
- Baseline - Digital Cameras
  - Soot Volume Fraction/Soot Temperature, Illumination, High Frame Rate with Automatic Positioning and Tracking, Low Light Level Ultraviolet, Mid Infra-Red
- Up to 36 Giga-Bytes of data storage

Combustion Chamber Features:

- Breech Lock Hinged Front Lid
- Replaceable Windows
- Provides Interfaces to PI-Specific Hardware

Chamber Specifications:

- 40 cm Internal Diameter
- 90 cm Overall Length
- 100 Free Liters
- Maximum pressure of 10 atmospheres

Window Specifications:

- 8 Windows, 12 cm Viewable Diameter
- 4 Pairs, 180 degrees apart
- Replaced from inside chamber
- No tools required, Racheting Mechanism

PI Hardware Specifications:

- 40 cm Diameter
- 60 cm Overall Length

Instrumentation Ring:

- Provides interfaces internal to chamber
- 3 Electrical Connectors, Water Cooling Ports (2)
- Vacuum Port, Gas Delivery Port
- Exhaust Vent Port, Sample Port

Additional Features:

Fluid System Specifications:

- Capable of Mixing 3 Gases
- Three 3.8 L Bottles up to 14 MPa (-2000 PSI) each
- Static Blending
  - Partial Pressures
  - ~0.1 % Accuracy with 2 ideal gases
  - Accommodates pre-mixed bottles
- Dynamic
  - Mass flow controllers
  - ~0.1% Accuracy
  - Flow Rate
  - Oxidizer: Up to 2910 cc/sec
  - Fuel: Up to 8.33 cc/sec
  - Chemical Bed and Particle Mesh Filters
  - Designed to clean: Methane, Propane, n-Hepthane, CO, CO_2, Sulfur Dioxide, Nitrous Oxide, plus others
- Gas Chromatograph

Data Acquisition Specifications:

- 48 Analong inputs, 16 Bits
- 1000 Khz sampling rates
- Stores 9 Gbytes
- High Rate Data Link: 20 Mbits/sec

Operations & Telescience:

The FCF will be teleoperated from the NASA Lewis Research Center Telescience Support Center. In concert with the Cleveland-based Operations Team, the Principal Investigator's experiment will be remotely monitored and controlled from the PI's homesite.

B. COMBUSTION MODULE (CM-1)

Combustion Module-1 (CM-1) is a state-of-the-art space laboratory for microgravity combustion science. It is 2.5 m (8 ft.) tall by 1.8 m (5 ft.) wide and weighs over 630 kg (1600 lb.). CM-1 can accommodate many experiments by burning a variety of gases and providing unique operating and measurement capabilities.

The first flight of CM-1 was on the Microgravity Science Laboratory-1 (MSL-1) Spacelab module. A key concept CM-1 demonstrates is the accommodation of a variety of combustion experiments through the use of experiment-unique chamber inserts called Experiment Mounting Structures (EMSs).

For MSL-1, CM-1 carried out two investigations, the Laminar Soot Processes (LSP) experiment and the Structure of Flame Balls at Low Lewis-number (SOFBALL) experiment. On orbit CM-1's chamber slide rails and quick disconnects enabled the crew to insert and connect the EMS for each investigation.

The capabilities of CM-1 are provided by a combination of 10 hardware subsystems and over 55,000 lines of flight software code. Each subsystem is described below:

Dedicated Experiment Processor:

CM-1's "brain" works with the crew's laptop computer to control CM-1.

Diagnostic Processor:

Digitizes, saves, and downlinks images from CM-1's cameras.

Exhaust Vent:

Cleans and vents combustion gases to space.

Experiment Mounting Structures

There are two chamber inserts of EMSs. The SOFBALL EMS has a high-energy spark ignitor, thermocouple rake, and radiometers. The LSP EMS has a fuel nozzle, hot wire ignitor, thermocouple rake, soot samplers, and radiometers.

Experiment Package:

Core of CM-1, contains the following:

- Combustion Chamber: 90-liter machined aluminum cylinder with 6 viewing ports
- Intensified Cameras: two light-enhancing cameras used to view flame balls from two angles
- Gas Chromatograph: that analyzes types and quantities of pre- and postcombustion SOFBALL gases
- Soot Volume Fraction: system that measures the amount of soot in an LSP flame by passing a lower-power laser beam through the flame
- Soot temperature System: two black-and-white cameras filtered to measure the temperatures of the LSP flames

Fluid Supply:

Gas supply and flow control system, safely distributes gas from 20 pressurized gas bottles.

Power Distributions:

Routes power to all CM-1 components.

VCR:
Contains four Hi-8 VCRs and records video of the flames.

Video Interface:
Routes CM-1 camera signals to the 15-cm (6-in.) CM-1 monitor for the crew and the ground team.

C. DROPLET COMBUSTION EXPERIMENT (DCE)

The DCE hardware primarily consists of the following subsystems: the experiment module, the avionics module, and the diagnostics subsystem. The experiment module contains a combustion chamber with provisions to mount environment gas supply bottles, a vent system to remove the burnt gases, a camcorder mounting system, and a crew view port. The heart of the experiment module is the Internal Apparatus (IA). The IA contains the droplet deployment and ignition mechanisms which are controlled by onboard microprocessors. The initial droplet diameters range from 1 mm to 5 mm. A droplet is formed by injecting the fuel through two opposed injectors. The injectors are retracted slightly to stabilize the droplet then rapidly removed to deploy the droplet in the field of view of the optical measurements apparatus. Two hot-wire igniters are brought near the droplet from opposite sides to ignite the flame while providing minimum disturbance to the droplet. After ignition, the igniters are retracted.

The combustion chamber pressure and temperature are recorded during an experiment. The diagnostic subsystem consists of a 35-mm-film camera running at 80 frames per second, a UV-sensitive intensified-array camera which captures the radiant emission from excited OH radicals at 310 nm wavelength, and camcorder which is used to monitor the experiment progress. The camcorder and the UV-flame views can be downlinked for examination by the investigators during the mission. The crew viewport can also be used to obtain still, color camera pictures of the flame by the crew as needed. The avionics module houses the electronic power supply and control boards. The key components of the avionics module can be replaced on-orbit by the crew members, in case of a failure. There are 21 high-pressure, premixed gas supply bottles containing predetermined oxygen/helium mixtures that are used to fill the combustion chamber according to DCE test matrix specifications.

D. MICROGRAVITY SMOLDERING COMBUSTION FLIGHT HARDWARE

The MSC experiment hardware is a Get Away Special Canister (GASCAN) payload. The payload is flown in the Shuttle Cargo Bay. The hardware design consists of two modules, a combustion module and an electronics module. The combustion module is comprised of two sealed chambers and a flow system. Each chamber provides the environment and hardware to conduct a combustion test. The chamber is designed for atmospheric test conditions with allowable pressure increase to three atmospheres. The chambers are semicircular cylinders that have a free volume of 20 liters and measure approximately 29 cm high with a 22 cm radius. Each chamber is presently instrumented for measurement of Interior pressure, chamber wall temperature (2), chamber gas temperature (4), and fuel sample temperature (12).

The flow system associated with the combustion chamber provides a constant mass flow to the fuel sample. It consists of a pressurized oxidizer tank, pressure regulator, solenoid isolation valves, flow restriction orifice, and pressure transducers (2). The system is designed to provide a pre-selected flow of 0.3 mm/sec through a 120 mm diameter tube. The hardware currently provides 1.0 mm/sec flow for 48 minutes nominal. The electronics module provides for all the experiment power, control, and data acquisition. It consists of a battery assembly (silver and zinc cells), data acquisition box (STD bus motherboard and printed circuit boards), power control unit, and igniter power unit. The power system has the capacity of 620 watt-hours on the nominal 28-volt DC battery.

The data acquisition system provides 12-bit resolution of 48 instrumentation channels and provides digital data storage of 512 kilobytes for pressure, temperature, and housekeeping data.

The experiment is automatically controlled via on-board software with no current downlink capability. The electronics design is capable of active control of the ignition and flow functions as well as data acquisition and imaging control. Each video camera and recorder has a two-hour capacity.

E. SOLID SURFACE COMBUSTION EXPERIMENT HARDWARE (SSCE)

The Solid Surface Combustion Experiment (SSCE) hardware consists of two modules accommodated in the Shuttle Middeck. Each module occupies the volume of two Middeck lockers. One module consists of a 38 liter volume sealed chamber. The chamber is a cylinder with two elliptical end domes and has dimensions of 50 cm internal length and a 34 cm internal diameter. The chamber has two orthogonal windows for process viewing, a hermetic connector for power and instrumentation wiring, and a gas fill port.

The second module consists of the power, data acquisition and control electronics, and imaging components. The power is provided by a 14-cell lead acid battery that provides 72 watt-hours at 28 VDC that is distributed to electronics at 28 VDC, 12 VDC, and 5 VDC. The data acquisition system provides for 12-bit resolution of 16 data channels and digital storage of 256 kilobytes.

Visual recording has been provided by either two 16 mm cine film cameras (24, 48, 64, 100, 150, or 200 fps) equipped with 200 foot film magazines, or one 16 mm cine film camera and one camcorder (accommodated Shuttle Crew Cannon L-1/L-2 camcorder).

The experiment hardware as currently used is automated with no provisions for real-time data transmittal.

F. TRANSITIONAL/TURBULENT GAS-JET DIFFUSION FLAME HARDWARE (TGDF)

The TGDF experiment is a study of a diffusion flame in the absence of buoyant-driven convection flows. The experiment focus is to define the effects of externally applied large scale structures in a laminar flow gas-jet flame.

The experiment is designed for operation on the Shuttle with the hardware accommodated within a 5-foot-long Get Away Special Canister (GAS-Can). The hardware consists of two main units, a combustion chamber and an attached electronics shelf. The 55 liter hermetically sealed combustion chamber provides a minimum 48 liters free volume. The chamber encloses the fuel system, the retractable igniter, the flame disturbance mechanism, two video cameras (one color, one B/W), a thermocouple rake, and three radiometers (two slice-type and one global). The chamber does not have viewing ports. The propane fuel system consists of a 75 cc fuel supply bottle, a pressure regulator, two solenoid isolation valves, a choked flow orifice, and a fuel nozzle. Flame disturbance is provided by an iris mechanism that is centered over the fuel nozzle. The iris is driven by a reciprocating arm which is driven by a stepper motor. The stepper motor with its associated control electronics allows operation of the iris over the required 1 to 5 Hz frequency range. The thermocouple rake has eight Type K (chromel/alumel) thermocouples for flame and gas temperature measurements. Pressure measurements are provided by three transducers.

Power, recording, and control of the experiment is provided by the components mounted on the electronics shelf. The shelf holds a 19-cell silver-zinc battery, system power control unit, the data acquisition and control system (DACS), igniter power unit, and two 8 mm video tape recorders. The DACS provides for the instrumentation signal processing through 12-bit analog/digital electronics. The signals are sampled at 50 Hz and recorded in memory chips. The experiment hardware is automated and self-powered, with no provision for real-time data transmittal.

G. MIDDECK GLOVEBOX

The Middeck Glovebox (MGBX) facility is an enclosed volume that provides physical isolation of various small-scale experiments from the middeck and enables crew member manipulation of these experiments through gloveports. The MGBX provides containment of powders, splinters, liquids, flames, or combustion products which may be produced from experiment operations. The MGBX occupies two standard lockers in the space shuttle middeck. The MGBX door opening to insert or retrieve experiment hardware is approximately 20.3 cm by 19.4 cm. The working volume is approximately 35 liters and 45 cm wide, 30 cm deep, and 25 cm high.

An air filtering system protects the middeck environment from experiment products. Forced air cooling can withdraw a maximum of 60 watts of experiment generated heat. Up to 60 watts of experiment power can be provided via a protected 28 Vdc line. A power converter box is also available which can provide +24Vdc, +5Vdc, +12Vdc, and -12Vdc lines.

The MGBX can be used in various modes of pressure and air circulation. The working area can serve as a sealed environment that is isolated from the crew cabin atmosphere, as a constantly recirculating atmosphere that is maintained at a pressure slightly lower than the middeck ambient, or as a working area open to the middeck. Airtight gloves or non-sealed cuffs are mounted in the two gloveports. Multipurpose filters remove particles, liquids, and reaction gases from the recirculated air. Pressure, humidity, and temperature sensors are utilized to monitor filter performance.

Video and 35mm cameras are the primary method utilized for gathering data. The MGBX has three CCD video cameras. The camera control electronics are contained within the MGBX, while the camera heads can be mounted external to the MGBX and positioned to view through the specialized video ports, or through the large window on top of the MGBX. The videoports allow the camera heads to swivel to view the entire working area. Both black and white and color video cameras are available. Three video recorders provide data storage, with digital data stored in the audio channels (up to three audio and three discrete channels of data can be recorded). Adjustable lighting, video port plugs, a backlight panel, a halogen flashlight, and a stray light window cover provide different photographic options.

The overall philosophy of the Glovebox program is to provide the ability to conduct smaller, less complex science experiments or technology demonstrations in a microgravity environment in a faster, better, and cheaper manner. The hardware development cycle runs approximately 2 to 3 years. At this time, multiple Glovebox Investigations in the disciplines of materials science, fluid physics, biotechnology, and combustion science have been flown on USML-2 (September 1995), USMP-3 (February 1996), and MSL-1 (July, 1997). The combustion science investigations have included Fiber Supported Droplet Combustion (FSDC), Comparative Soot Diagnostics (CSD), Forced Flow Flamespreading Test (FFFT), and Radiative Ignition and Transition to Spread Investigation (RITSI). The FFFT was also flown on the Russian Mir Space Station in November 1995 as was a reflight of Candle Flames in Microgravity (CFM), which flew earlier on USML-1. Future Glovebox flight opportunities thus far defined include the Fourth United States Microgravity Payload Mission (USMP-4) in November, 1997, and further missions to the Russian Mir Space Station.

H. ISS MICROGRAVITY SCIENCE GLOVEBOX

The Microgravity Science Glovebox (MSG) for the International Space Station (ISS) will be a larger version of the Middeck Glovebox. The MSG will have a larger work area to allow larger size and mass experiments to be conducted inside the Glovebox. The MSG will provide up to 1000 watts of experiment power, a vent connection, a nitrogen connection, an airlock, illumination, color and black and white video cameras and recorders for viewing, recording, or downlinking, and miscellaneous tools and cleaning supplies. It is envisioned that experiments will be conducted in the areas of fluid physics, combustion science, materials science, and biotechnology. The MSG will be developed by the European Space Agency and will be available for use soon after the deployment of the U.S. Laboratory Module of the ISS.

I. SOUNDING ROCKETS

Two microgravity combustion experiments, Spread Across liquids (SAL) and Diffusive and Radiative Transport in Fires (DARTFire) are being flown as sounding rocket experiments, utilizing the Terrier-Black Brant as a carrier. Three SAL tests and 3 DARTFire tests were flown to date. Both experiments are scheduled for a same -day test in September 1997, and SAL is scheduled for 4 additional tests from 1998 through 2001. In addition, the Space Acceleration Measurement System for Free-Flyers (SAMS-FF) is being flown as a secondary experiment with the this last test of the DARTFire Experiment. In the configuration being employed, these sounding rockets provide approximately 7 minutes of quality microgravity time for an experiment weighing 450 pounds. The experiment can be up to 10 feet long and is fitted inside cylindrical skin sections that are optionally 15 inches or 22 inches in diameter.

In the SAL experiment, liquid fuel is loaded into a 30 cm long by 2 cm wide by 2.5 cm deep tray located inside a 10 cm by 10 cm cross-section flow duct used to provide a controlled low-speed air flow over the fuel surface. Hot wire ignitors are located at each end of the tray to provide ignition of multiple burns in either direction relative to the imposed air flow. Thermocouples are placed at several locations in the in the fuel and surrounding gas. The sides of the fuel tray are constructed of schlieren-quality windows to allow viewing of the fuel from the side. In addition to standard thermocouple and pressure transducer instrumentation, the SAL experiment includes four color CCD cameras, 2 Particle Imaging Velocimetry systems for flow visualization, a rainbow schlieren system, and an infrared camera. For the future tests the gas flow diagnostic equipment is added to correlate fuel flow patterns with gas phase flow patterns. In addition, the fuel tray dimensions will be varied for different test conditions in order to assess the analytical model differentiation to fuel tray geometry.

The DARTFire Experiment tests flames on the surface of a solid PMMA sample positioned with the sample surface flush with the floor of a flow duct. The induced entry condition laminar flow can be accurately preset to any flow rate between 1 cm/sec and 20 cm/sec using oxygen concentrations of up to 70 percent. The experiment contains 2 test ducts that are capable of running tests with different test conditions either simultaneously or in sequence. The test samples are each instrumented with 8 solid and gas phase thermocouples. A calibrated intensified array camera with a 6 filter wheel records the side view of both test flames to obtain color and ultraviolet range data. A calibrated infrared camera with a 6 filter wheel also records the side view of the flame obtaining chemical species data. Spot radiometers measure the temperature of sample surfaces. Also, 1 test duct has a laser for uniformly radiating the sample surface, providing variable radiative flux between 0 and 2 watts/cm^2. The raw video data is post processed by the NASA Lewis Research Center Graphics Visualization Laboratory into digital engineering data that is ready for computational analysis by the science team.

The SAMS-FF experiment will provide a high-quality detailed characterization of the sounding rocket microgravity environment. This experiment will gather data at a high frequency triaxial sensor head and a roll rate sensor. The raw data will be post processed by the SAMS project and made available to the DARTFire Science team and prospective sounding rocket experimenters.

II. GROUND-BASED FACILITIES

Investigators often need to conduct reduced gravity experiments in ground-based facilities during the experiment definition and technology development phases. The NASA ground-based reduced-gravity research facilities that support the MRD combustion program includes two drop towers at Lewis Research Center (LeRC) and a KC-135 aircraft that is based at JSC but will fly 6-10 campaigns per year from LeRC. NASA data handling resources include wide area network connectivity, supercomputing, and directory services for NASA and non-NASA data holdings. Each of these facilities and resources has different capabilities and characteristics that should be considered by an investigator to determine which are best suited for conducting combustion science research.

A. 2.2-SESOND DROP TOWER

The 2.2-Second Drop Tower at LeRC provides 2.2 seconds of low-gravity test time for experiment packages consisting of up to 125 kilograms of hardware. The experiment package is enclosed in a drag shield, and a gravitational acceleration of less than 10^{-5}g is obtained during the fall since the experiment package falls freely within the drag shield. The only external force acting on the falling experiment packages is the air drag associated with the relative motion of the package within the enclosure of the drag shield. At the end of a drop, the drag shield and the enclosed experiment are decelerated in a 2.2-meter-deep sand pit by the deceleration spikes. The peak deceleration rate can be as high as 70gs. Eight to twelve tests can be performed in one day. Data from experiments are acquired by high-speed motion picture cameras with rates of up to 1,000 frames per second and by on-board data acquisition systems used to record data supplied by thermocouples, pressure transducers, and flow meters.

B. 5.18-SECOND ZERO-GRAVITY FACILITY

The 5.18-Second Zero-Gravity Facility at LeRC has a 132-meter free fall distance in a drop chamber which is evacuated by a series of pumpdown procedures to a final pressure of 1 Pa. Experiments utilizing hardware weighing up to 450 kilograms are mounted in a one-meter diameter by 3.4-meter high drop bus. Gravitational acceleration of less than 10^{-5} g is obtained. At the end of the drop, the bus is decelerated in a 6.1-meter deep container filled with small pellets of expanded polystyrene. The deceleration rate is typically 60g (for 20 millisec). Visual data is acquired through the use of high-speed motion picture cameras. Also, other data such as pressures, temperatures, and accelerations are either recorded on board with various data acquisition systems or are transmitted to a control room by a telemetry system capable of transmitting 18 channels of continuous data. Due to the complexity of drop chamber operations and time required for pump-down of the drop chamber, typically only one test is performed per day.

C. REDUCED-GRAVITY AIRCRAFT

The KC-135 can provide periods of low gravity for up to 23-second intervals. The aircraft accommodates a variety of experiments and is often used to refine space flight experiment equipment and techniques and to train crew members in experiment procedures, thus giving investigators and crew members valuable experience in working in a weightless environment. Qualified observers or operators may fly with their experiment packages. The KC-135 obtains a low-gravity environment by flying a parabolic trajectory. Gravity levels twice those of normal gravity occur during the initial and final portions of the trajectory, while the brief pushover at the top of the parabola produces less than one percent of Earth's gravity (10^{-2} g). The interior KC-135 bay dimensions are 6 feet wide and 6.4 feet high by 60 feet long . Several experiments, including a combination of attached and free-floated hardware (which can provide effective gravity levels of nominally 10^{-3} g for periods of up to 10 seconds) can be integrated in a single flight. The aircraft can supply a total of 80 amps of 28 volt dc, 50 amps of 110 volt ac 60Hz and 20 amps open each phase of 3 phase 110 volt ac 400 Hz. These are maximum powers available to all users. Instrumentation and data collection capabilities must be contained in the experiment packages.

III. DIAGNOSTICS/MEASUREMENTS CAPABILITY

NASA has adapted or developed a large number of diagnostic/measurement techniques for use in the Microgravity Combustion research program, with some of these techniques, including particle imaging velocimetry, laser light scattering, and Rainbow Schlieren Deflectometry, having already been demonstrated in flight. A brief list of techniques already in use or under development, and possibly available for use in future programs, appears below.

1. Soot Temperature Measurements Using Pyrometric Techniques

2. Rainbow Schlieren For Measurement of Temperature Distributions

3. Planar 2D Temperature and CH and OH Concentration Measurements Via Rayleigh Scattering and Laser-Induced Fluorescence

4. Light Sheet Flow Visualization and/or Velocimetry

5. Laser Doppler Velocimetry

6. Liquid Surfaces Temperature and Vapor Phase Concentration Measurements Via Exciplex Fluorescence

7. Determination of CH_4, CO_2, and H_2O Concentrations Via Line Absorption Techniques

8. Planar Laser-Induced Fluorescence for Determination of Flame Front Position

9. Particle Imaging Velocimetry

10. Liquid Phase Thermometry and Fluorescence of Aromatics to Evaluate Droplet Surface Transport and Internal Flow

11. Diode Laser Wavelength Modulation Spectroscopy For Quantitative Molecular Oxygen Concentration Measurements.

12. Compact Laser-Diode CCD Array for Measuring Instantaneous Radial Variations of the Temperature Fields Within a Burning Droplet and in the Gas-Phase Around it while Also Instantaneously Measuring Droplet Size and Regression rate.

13. Laser-Induced Incandescence for measurement of soot volume fractions.

For further information on the state of development of these techniques for use in Microgravity Combustion research activities, please contact Dr. Paul Greenberg (NASA Lewis Research Center) at 216-433-3621.

APPENDIX C
NRA-97-HEDS-01

INSTRUCTIONS FOR RESPONDING TO NASA RESEARCH ANNOUNCEMENTS

(JANUARY 1997)

A. General.

(1) Proposals received in response to a NASA Research Announcement (NRA) will be used only for evaluation purposes. NASA does not allow a proposal, the contents of which are not available without restriction from another source, or any unique ideas submitted in response to an NRA to be used as the basis of a solicitation or in negotiation with other organizations, nor is a pre-award synopsis published for individual proposals.

(2) A solicited proposal that results in a NASA award becomes part of the record of that transaction and may be available to the public on specific request; however, information or material that NASA and the awardee mutually agree to be of a privileged nature will be held in confidence to the extent permitted by law, including the Freedom of Information Act.

(3) NRA's contain programmatic information and certain requirements which apply only to proposals prepared in response to that particular announcement. These instructions contain the general proposal preparation information which applies to responses to all NRAs.

(4) A contract, grant, cooperative agreement, or other agreement may be used to accomplish an effort funded in response to an NRA. NASA will determine the appropriate instrument. Contracts resulting from NRA's are subject to the Federal Acquisition Regulation and the NASA FAR Supplement. Any resultant grants or cooperative agreements will be awarded and administered in accordance with the NASA Grant and Cooperative Agreement Handbook (NPG 5800.1).

(5) NASA does not have mandatory forms or formats for responses to NRA's; however, it is requested that proposals conform to the guidelines in these instructions. NASA may accept proposals without discussion; hence, proposals should initially be as complete as possible and be submitted on the proposers' most favorable terms.

(6) To be considered for award, a submission must, at a minimum, present a specific project within the areas delineated by the NRA; contain sufficient technical and cost information to permit a meaningful evaluation; be signed by an official authorized to legally bind the submitting organization; not merely offer to perform standard services or to just provide computer facilities or services; and not significantly duplicate a more specific current or pending NASA solicitation.

B. NRA-Specific Items. Several proposal submission items appear in the NRA itself: the unique NRA identifier; when to submit proposals; where to send proposals; number of copies required; and sources for more information. Items included in these instructions may be supplemented by the NRA.

C. Proposal Content. The following information is needed to permit consideration in an objective manner. NRAs will generally specify topics for which additional information or greater detail is desirable. Each proposal copy shall contain all submitted material, including a copy of the transmittal letter if it contains substantive information.

(1) *Transmittal Letter or Prefatory Material.*

(i) The legal name and address of the organization and specific division or campus identification if part of a larger organization;

(ii) A brief, scientifically valid project title intelligible to a scientifically literate reader and suitable for use in the public press;

(iii) Type of organization: e.g., profit, nonprofit, educational, small business, minority, women-owned, etc.;

(iv) Name and telephone number of the principal investigator and business personnel who may be contacted during evaluation or negotiation;

(v) Identification of other organizations that are currently evaluating a proposal for the same efforts;

(vi) Identification of the NRA, by number and title, to which the proposal is responding;

(vii) Dollar amount requested, desired starting date, and duration of project;

(viii) Date of submission; and

(ix) Signature of a responsible official or authorized representative of the organization, or any other person authorized to legally bind the organization (unless the signature appears on the proposal itself).

(2) *Restriction on Use and Disclosure of Proposal Information.* Information contained in proposals is used for evaluation purposes only. Offerors or quoters should, in order to maximize protection of trade secrets or other information that is confidential or privileged, place the following notice on the title page of the proposal and specify the information subject to the notice by inserting an appropriate identification in the notice. In any event, information contained in proposals will be protected to the extent permitted by law, but NASA assumes no liability for use and disclosure of information not made subject to the notice.

Notice

Restriction on Use and Disclosure of Proposal Information

The information (data) contained in [insert page numbers or other identification] of this proposal constitutes a trade secret and/or information that is commercial or financial and confidential or privileged. It is furnished to the Government in confidence with the understanding that it will not, without permission of the offeror, be used or disclosed other than for evaluation purposes; provided, however, that in the event a contract (or other agreement) is awarded on the basis of this proposal the Government shall have the right to use and disclose this information (data) to the extent provided in the contract (or other agreement). This restriction does not limit the Government's right to use or disclose this information (data) if obtained from another source without restriction.

(3) *Abstract*. Include a concise (200-300 word if not otherwise specified in the NRA) abstract describing the objective and the method of approach.

(4) *Project Description.*

(i) The main body of the proposal shall be a detailed statement of the work to be undertaken and should include objectives and expected significance; relation to the present state of knowledge; and relation to previous work done on the project and to related work in progress elsewhere. The statement should outline the plan of work, including the broad design of experiments to be undertaken and a description of experimental methods and procedures. The project description should address the evaluation factors in these instructions and any specific factors in the NRA. Any substantial collaboration with individuals not referred to in the budget or use of consultants should be described. Subcontracting significant portions of a research project is discouraged.

(ii) When it is expected that the effort will require more than one year, the proposal should cover the complete project to the extent that it can be reasonably anticipated. Principal emphasis should be on the first year of work, and the description should distinguish clearly between the first year's work and work planned for subsequent years.

(5) *Management Approach*. For large or complex efforts involving interactions among numerous individuals or other organizations, plans for distribution of responsibilities and arrangements for ensuring a coordinated effort should be described.

(6) *Personnel*. The principal investigator is responsible for supervision of the work and participates in the conduct of the research regardless of whether or not compensated under the award. A short biographical sketch of the principal investigator, a list of principal publications and any exceptional qualifications should be included. Omit social security number and other personal items which do not merit consideration in evaluation of the proposal. Give similar biographical information on other senior professional personnel who will be directly associated with the project. Give the names and titles of any other scientists and technical personnel associated substantially with the project in an advisory capacity. Universities should list the approximate number of students or other assistants, together with information as to their level of academic attainment. Any special industry-university cooperative arrangements should be described.

(7) *Facilities and Equipment.*

(i) Describe available facilities and major items of equipment especially adapted or suited to the proposed project, and any additional major equipment that will be required. Identify any Government-owned facilities, industrial plant equipment, or special tooling that are proposed for use. Include evidence of its availability and the cognizant Government points of contact.

(ii) Before requesting a major item of capital equipment, the proposer should determine if sharing or loan of equipment already within the organization is a feasible alternative. Where such arrangements cannot be made, the proposal should so state. The need for items that typically can be used for research and non-research purposes should be explained.

(8) *Proposed Costs.*

(i) Proposals should contain cost and technical parts in one volume: do not use separate "confidential" salary pages. As applicable, include separate cost estimates for salaries and wages; fringe benefits; equipment; expendable materials and supplies; services; domestic and foreign travel; ADP expenses; publication or page charges; consultants; subcontracts; other miscellaneous identifiable direct costs; and indirect costs. List salaries and wages in appropriate organizational categories (e.g., principal investigator, other scientific and engineering professionals, graduate students, research assistants, and technicians and other non-professional personnel). Estimate all staffing data in terms of staff-months or fractions of full-time.

(ii) Explanatory notes should accompany the cost proposal to provide identification and estimated cost of major capital equipment items to be acquired; purpose and estimated number and lengths of trips planned; basis for indirect cost computation (including date of most recent negotiation and cognizant agency); and clarification of other items in the cost proposal that are not self-evident. List estimated expenses as yearly requirements by major work phases.

(iii) Allowable costs are governed by FAR Part 31 and the NASA FAR Supplement Part 1831 (and OMB Circulars A-21 for educational institutions and A-122 for nonprofit organizations).

(9) *Security*. Proposals should not contain security classified material. If the research requires access to or may generate security classified information, the submitter will be required to comply with Government security regulations.

(10) *Current Support*. For other current projects being conducted by the principal investigator, provide title of project, sponsoring agency, and ending date.

(11) *Special Matters*.

(i) Include any required statements of environmental impact of the research, human subject or animal care provisions, conflict of interest, or on such other topics as may be required by the nature of the effort and current statutes, executive orders, or other current Government-wide guidelines.

(ii) Proposers should include a brief description of the organization, its facilities, and previous work experience in the field of the proposal. Identify the cognizant Government audit agency, inspection agency, and administrative contracting officer, when applicable.

D. Renewal Proposals.

(1) Renewal proposals for existing awards will be considered in the same manner as proposals for new endeavors. A renewal proposal should not repeat all of the information that was in the original proposal. The renewal proposal should refer to its predecessor, update the parts that are no longer current, and indicate what elements of the research are expected to be covered during the period for which support is desired. A description of any significant findings since the most recent progress report should be included. The renewal proposal should treat, in reasonable detail, the plans for the next period, contain a cost estimate, and otherwise adhere to these instructions.

(2) NASA may renew an effort either through amendment of an existing contract or by a new award.

E. Length. Unless otherwise specified in the NRA, effort should be made to keep proposals as brief as possible, concentrating on substantive material. Few proposals need exceed 15-20 pages. Necessary detailed information, such as reprints, should be included as attachments. A complete set of attachments is necessary for each copy of the proposal. As proposals are not returned, avoid use of "one-of-a-kind" attachments.

F. Joint Proposals.

(1) Where multiple organizations are involved, the proposal may be submitted by only one of them. It should clearly describe the role to be played by the other organizations and indicate the legal and managerial arrangements contemplated. In other instances, simultaneous submission of related proposals from each organization might be appropriate, in which case parallel awards would be made.

(2) Where a project of a cooperative nature with NASA is contemplated, describe the contributions expected from any participating NASA investigator and agency facilities or equipment which may be required. The proposal must be confined only to that which the proposing organization can commit itself. "Joint" proposals which specify the internal arrangements NASA will actually make are not acceptable as a means of establishing an agency commitment.

G. Late Proposals. A proposal or modification received after the date or dates specified in an NRA may be considered if doing so is in the best interests of the Government.

H. Withdrawal. Proposals may be withdrawn by the proposer at any time before award. Offerors are requested to notify NASA if the proposal is funded by another organization or of other changed circumstances which dictate termination of evaluation.

I. <u>Evaluation Factors.</u>

(1) Unless otherwise specified in the NRA, the principal elements (of approximately equal weight) considered in evaluating a proposal are its relevance to NASA's objectives, intrinsic merit, and cost.

(2) Evaluation of a proposal's relevance to NASA's objectives includes the consideration of the potential contribution of the effort to NASA's mission.

(3) Evaluation of its intrinsic merit includes the consideration of the following factors of equal importance:

(i) Overall scientific or technical merit of the proposal or unique and innovative methods, approaches, or concepts demonstrated by the proposal.

(ii) Offeror's capabilities, related experience, facilities, techniques, or unique combinations of these which are integral factors for achieving the proposal objectives.

(iii) The qualifications, capabilities, and experience of the proposed principal investigator, team leader, or key personnel critical in achieving the proposal objectives.

(iv) Overall standing among similar proposals and/or evaluation against the state-of-the-art.

(4) Evaluation of the cost of a proposed effort may include the realism and reasonableness of the proposed cost and available funds.

J. <u>Evaluation Techniques</u>. Selection decisions will be made following peer and/or scientific review of the proposals. Several evaluation techniques are regularly used within NASA. In all cases proposals are subject to scientific review by discipline specialists in the area of the proposal. Some proposals are reviewed entirely in-house, others are evaluated by a combination of in-house and selected external reviewers, while yet others are subject to the full external peer review technique (with due regard for conflict-of-interest and protection of proposal information), such as by mail or through assembled panels. The final decisions are made by a NASA selecting official. A proposal which is scientifically and programmatically meritorious, but not selected for award during its initial review, may be included in subsequent reviews unless the proposer requests otherwise.

K. <u>Selection for Award.</u>

(1) When a proposal is not selected for award, the proposer will be notified. NASA will explain generally why the proposal was not selected. Proposers desiring additional information may contact the selecting official who will arrange a debriefing.

(2) When a proposal is selected for award, negotiation and award will be handled by the procurement office in the funding installation. The proposal is used as the basis for negotiation. The contracting officer may request certain business data and may forward a model award instrument and other information pertinent to negotiation.

L. <u>Cancellation of NRA</u>. NASA reserves the right to make no awards under this NRA and to cancel this NRA. NASA assumes no liability for canceling the NRA or for anyone's failure to receive actual notice of cancellation.

APPENDIX D
NRA-97-HEDS-01

NASA RESEARCH ANNOUNCEMENT (NRA) SCHEDULE

MICROGRAVITY COMBUSTION SCIENCE: RESEARCH AND FLIGHT EXPERIMENT OPPORTUNITIES

All proposals submitted in response to this Announcement are due on the date and at the address given below by the close of business (4:30 PM EST). NASA reserves the right to consider proposals received after this deadline if such action is judged to be in the interest of the U.S. Government. A complete schedule of the review of the proposals is given below:

NRA Release Date: ....October 14, 1997

Letter of Intent Due: ....December 1, 1997

Proposal Due: ....January 16, 1998

Submit Proposal to:

Dr. Merrill K. King
c/o Information Dynamics Inc.
Subject: NASA Research Proposal (NRA-97-HEDS-01)
300 D Street, SW, Suite 801
Washington, DC 20024

Telephone number for delivery services: (202) 479-2609

Final Selections: ....August, 1998

Funding commences: ....October, 1998
(dependent upon actual selection and procurement process)

FORM A

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
OFFICE OF LIFE & MICROGRAVITY SCIENCES & APPLICATIONS
MICROGRAVITY RESEARCH DIVISION

SOLICITED PROPOSAL APPLICATION
PLEASE FOLLOW INSTRUCTIONS CAREFULLY

LEAVE BLANK

NUMBER

REVIEW GROUP

DATE RECEIVED

1. COMPLETE TITLE OF PROJECT

2. PRINCIPAL INVESTIGATOR/PROGRAM DIRECTOR *(First, middle, and last name; degrees; position title)*

3. COMPLETE MAILING ADDRESS
Internal Mail Code or Location
Office or Organization Division
Agency/Center, Company, or Institution
Street or P.O. Box
City, State, Zip Code

4. TELEPHONE NUMBER *(area code, number, extension)*
FAX NUMBER
E-MAIL ADDRESS

5. CONGRESSIONAL DISTRICT

6. SOCIAL SECURITY #

7. IS THIS PROPOSAL ☐ NEW ☐ RENEWAL ☐ REVISED

8. HAS THIS PROPOSAL (OR SIMILAR REQUEST) BEEN SUBMITTED TO NASA OR ANY OTHER AGENCY?
☐ No ☐ Yes IF YES, SPECIFY AGENCY AND YEAR SUBMITTED:

9. CO-INVESTIGATORS *(First, middle, and last name; degrees)*

10. CO-INVESTIGATOR'S ORGANIZATION

11. DATES OF ENTIRE PROPOSED PROJECT PERIOD
From:
Through:

12. COSTS REQUESTED FOR FIRST 12-MONTH BUDGET PERIOD
12a. Direct Costs $
12b. Total Costs $

13. COSTS REQUESTED FOR ENTIRE PROPOSED PROJECT PERIOD
13a. Direct Costs $
13b. Total Costs $

14. APPLICANT ORGANIZATION *(Organization Name)*

15. TYPE OF ORGANIZATION
☐ Non Profit ☐ For Profit *(General)* ☐ For Profit *(Small Business)* ☐ Public, Specify: ☐ Federal ☐ State ☐ Local

16. ORGANIZATION OFFICIAL TO BE NOTIFIED IF AN AWARD IS MADE *(Name, title, address and telephone number)*

17. OFFICIAL SIGNING FOR APPLICANTORGANIZATION *(Name, title, and telephone number)*

18. PRINCIPAL INVESTIGATOR/PROGRAM DIRECTOR ASSURANCE: I agree to accept responsibility for the scientific conduct of the project and to provide the required progress reports if a grant is awarded as a result of this application. Willful provision of false information is a criminal offense (U.S. Code, Title 18, Section 1001).

SIGNATURE OF PERSON NAMED IN 2
(In ink "Per" signature not acceptable.)

DATE

19. CERTIFICATION AND ACCEPTANCE: I certify that the statements herein are true and complete to the best of my knowledge, and accept the obligation to comply with NASA terms and conditions if a grant is awarded as the result of this application. A willfully false certification is a criminal offense (U.S. Code, Title 18, Section 1001).

SIGNATURE OF PERSON NAMED IN 17
(In ink "Per" signature not acceptable.)

DATE

FORM B

PRINCIPAL INVESTIGATOR/PROGRAM DIRECTOR: ______________________

DETAILED BUDGET FOR 12-MONTH BUDGET PERIOD DIRECT COSTS ONLY		FROM		THROUGH	
Duplicate this form for each year of grant support requested		DOLLAR AMOUNT REQUESTS *(Omit cents)*			
PERSONNEL *(Applicant Organization Only)*					
NAME	**ROLE IN PROJECT**	**EFFORT ON PROJECT**	**SALARY**	**FRINGE BENEFITS**	**TOTALS**
	Principal Investigator				
	SUBTOTALS →				
CONSULTANT COSTS					
EQUIPMENT *(Itemize, use additional sheet if needed)*					
SUPPLIES *(Itemize by category, use additional sheet if needed)*					
TRAVEL	DOMESTIC				
	FOREIGN				
OTHER EXPENSES *(Itemize by category, use additional sheet if needed)*					

TOTAL DIRECT COSTS FOR FIRST 12-MONTH BUDGET PERIOD ***(Item 12a, Form A)***	**$**
INDIRECT COSTS FOR FIRST 12-MONTH BUDGET PERIOD	**$**
TOTAL COSTS FOR FIRST 12-MONTH BUDGET PERIOD ***(Item 12b, Form A)***	**$**

FORM C

PRINCIPAL INVESTIGATOR/PROGRAM DIRECTOR: ______________________

BUDGET FOR ENTIRE PROJECT PERIOD DIRECT COSTS ONLY

BUDGET CATEGORY TOTALS		1st BUDGET PERIOD	ADDITIONAL YEARS OF SUPPORT REQUESTED		
			2nd	3rd	4th
PERSONNEL (Salary and Fringe Benefits) (Applicant organization only)					
CONSULTANT COSTS					
EQUIPMENT					
SUPPLIES					
TRAVEL	DOMESTIC				
	FOREIGN				
OTHER EXPENSES					
TOTAL DIRECT COSTS FOR EACH BUDGET PERIOD		**$**	**$**	**$**	**$**
TOTAL INDIRECT COSTS FOR EACH BUDGET PERIOD		**$**	**$**	**$**	**$**
TOTAL DIRECT + INDIRECT COSTS FOR EACH PERIOD		**$**	**$**	**$**	**$**
TOTAL DIRECT + INDIRECT COSTS FOR ENTIRE PROJECT					**$**

JUSTIFICATION FOR UNUSUAL EXPENSES (Detail Justification in Cost Section of Proposal)

FORM D

CERTIFICATION REGARDING DRUG-FREE WORKPLACE REQUIREMENTS

This certification is required by the regulations implementing the Drug-Free Workplace Act of 1988, 34 CFR Part 85, Subpart F. The regulations, published in the January 31, 1989 Federal Register, require certification by grantees, prior to award, that they will maintain a drug-free workplace. The certification set out below is a material representation of fact upon which reliance will be placed when the agency determines to award the grant. False certification or violation of the certification shall be grounds for suspension of payments, suspension or termination of grants, or government-wide suspension or debarment (see 34 CFR Part 85, Sections 85.615 and 85.620).

I. GRANTEES OTHER THAN INDIVIDUALS

A. The grantee certifies that it will provide a drug-free workplace by:

(a) Publishing a statement notifying employees that the unlawful manufacture, distribution, dispensing, possession or use of a controlled substance is prohibited in the grantee's workplace and specifying the actions that will be taken against employees for violation of such prohibition;

(b) Establishing a drug-free awareness program to inform employees about --

(1)The dangers of drug abuse in the workplace;

(2)The grantees policy of maintaining a drug-free workplace;

(3)Any available drug counseling, rehabilitation, and employee assistance programs; and

(4)The penalties that may be imposed upon employees for drug abuse violations occurring in the workplace;

(c) Making it a requirement that each employee to be engaged in the performance of the grant be given a copy of the statement required by paragraph (a);

(d) Notifying the employee in the statement required by paragraph (a) that, as a condition of employment under the grant, the employee will --

(1)Abide by the terms of the statement; and

(2)Notify the employer of any criminal drug statute conviction for a violation occurring in the workplace no later than five days after such conviction;

(e) Notifying the agency within ten days after receiving notice under subparagraph (d) (2) from an employee or otherwise receiving actual notice of such conviction;

(f) Taking one of the following actions, within 30 days of receiving notice under subparagraph (d) (2), with respect to any employee who is so convicted --

(1)Taking appropriate personnel action against such an employee, up to and including termination; or

(2)Requiring such employee to participate satisfactorily in a drug abuse assistance or rehabilitation program approved for such purposes by a Federal, State, or Local health, Law enforcement, or other appropriate agency;

(g)Making a good faith effort to continue to maintain a drug-free workplace through implementation of paragraphs (a), (b), (c), (d), (e), and (f).

B. The grantee shall insert in the space provided below the site(s) for the performance or work done in connection with the specific grant: Place of Performance (Street address, city, county, state, zip code)

____

____

Check ____ if there are workplaces on file that are not identified here.

II. GRANTEES WHO ARE INDIVIDUALS

The grantee certifies that, as a condition of the grant, he or she will not engage in the unlawful manufacture, distribution, dispensing, possession or use of a controlled substance in conducting any activity with the grant.

____

Organization Name AO or NRA Number and Title

____

Printed Name and Title of Authorized Representative

____

Signature Date

____

Printed Principal Investigator Name Proposal Title

FORM E

CERTIFICATION REGARDING
DEBARMENT, SUSPENSION, AND OTHER RESPONSIBILITY MATTERS
PRIMARY COVERED TRANSACTIONS

This certification is required by the regulations implementing Executive Order 12549, Debarment and Suspension, 34 CFR Part 85, Section 85.510, Participants' responsibilities. The regulations were published as Part VII of the May 28, 1988 Federal Register (pages 19160-19211). Copies of the regulations may be obtained by contacting the U.S. Department of Education, Grants and Contracts Service, 400 Maryland Avenue, SW (Room 3633 GSA Regional Office Building No. 3), Washington, DC 20202-4725, telephone (202) 732-2505.

A. The applicant certifies that it and its principals:

(a) Are not presently debarred, suspended, proposed for debarment, declared ineligible, or voluntarily excluded from covered transactions by any Federal department or agency;
(b) Have not within a three-year period preceding this application been convicted or had a civil judgment rendered against them for commission of fraud or a criminal offense in connection with obtaining, attempting to obtain, or performing a public (Federal, State, or Local) transaction or contract under a public transaction; violation of Federal or State antitrust statutes or commission of embezzlement, theft, forgery, bribery, falsification or destruction of records, making false statements, or receiving stolen property;
(c) Are not presently indicted for or otherwise criminally or civilly charged by a government entity (Federal, State, or Local) with commission of any of the offenses enumerated in paragraph A.(b) of this certification; and
(d) Have not within a three-year period preceding this application/proposal had one or more public transactions (Federal, State, or Local) terminated for cause or default; and

B. Where the applicant is unable to certify to any of the statements in this certification, he or she shall attach an explanation to this application.

C. Certification Regarding Debarment, Suspension, Ineligibility and Voluntary Exclusion - Lowered Tier Covered Transactions (Subgrants or Subcontracts)

(a) The prospective lower tier participant certifies, by submission of this proposal, that neither it nor its principles is presently debarred, suspended, proposed for debarment, declared ineligible, or voluntarily excluded from participation in this transaction by any Federal department of agency.
(b) Where the prospective lower tier participant is unable to certify to any of the statements in this certification, such prospective participant shall attach an explanation to this proposal.

____
Organization Name AO or NRA Number and Title

____
Printed Name and Title of Authorized Representative

____
Signature Date

____
Printed Principal Investigator Name Proposal Title

FORM F

CERTIFICATION REGARDING LOBBYING

As required by S 1352 Title 31 of the U.S. Code for persons entering into a grant or cooperative agreement over $100,000, the applicant certifies that:

(a) No Federal appropriated funds have been paid or will be paid by or on behalf of the undersigned, to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, in connection with making of any Federal grant, the entering into of any cooperative, and the extension, continuation, renewal, amendment, or modification of any Federal grant or cooperative agreement;

(b) If any funds other than Federal appropriated funds have been paid or will be paid to any person for influencing or attempting an officer or employee of any agency, Member of Congress, an or an employee of a Member of Congress in connection with this Federal grant or cooperative agreement, the undersigned shall complete Standard Form - LLL, "Disclosure Form to Report Lobbying," in accordance with its instructions.

(c) The undersigned shall require that the language of this certification be included in the award documents for all subawards at all tiers (including subgrants, contracts under grants and cooperative agreements, and subcontracts), and that all subrecipients shall certify and disclose accordingly.

This certification is a material representation of fact upon which reliance was placed when this transaction was made or entered into. Submission of this certification is a prerequisite for making or entering into this transaction imposed by S1352, title 31, U.S. Code. Any person who fails to file the required certification shall be subject to a civil penalty of not less than $10,000 and not more than $100,000 for each such failure.

____

Organization Name AO or NRA Number and name

____

Printed Name and Title of Authorized Representative

____

Signature Date

____

Printed Principal Investigator Name Proposal Title

FORM G

Principal Investigator: ________________________________

Proposal Title (1st few words): ________________________________

RESOURCES REQUESTED FROM NASA

	2.2 sec. drop tower	5 sec. drop tower	low-g-aircraft	Other
Please specify the average yearly resources requested:				
Ground based facilities (# of drops or trajectories; if other, specify)				
If ground based facilities were requested what supporting services are required?				
Rig Frame (Yes / No)		**N/A**		**N/A**
General Purpose Combustion Rig * (Yes / No)		**N/A**	**N/A**	**N/A**
Diagnostic Rig #1 - Central Chamber * (Yes / No)		**N/A**	**N/A**	**N/A**
Diagnostic Rig #2 - Burner adjacent to palette * (Yes / No)		**N/A**	**N/A**	**N/A**
Data Acquisition & Control System (Yes / No)				**N/A**
Fiber Optic Transmitter (video signals) (Yes / No)		**N/A**	**N/A**	**N/A**
28 V Battery Packs (Yes / No)		**N/A**		**N/A**
Vacuum Pumps (Yes / No)				**N/A**
Consumable Gases (Type and SCF)				**N/A**
Electrical Technician (# of Hours)				**N/A**
Mechanical Technician (# of Hours)				**N/A**
Instrumentation Support (# of Hours)				**N/A**
Other Resources				
Computational Microgravity Laboratory * (specify # of hours)	**N/A**	**N/A**	**N/A**	
General Purpose Computers * (specify # of hours)	**N/A**	**N/A**	**NA**	
Motion Analysis & Object Tracking System (Tracker) *	**N/A**	**N/A**	**N/A**	
Film Development (# of Rolls)	**N/A**	**N/A**	**N/A**	
Other				

* See the following page for a brief description of these rigs or services.

Note: All of the above mentioned resources are limited in supply. NASA will work with successful proposers to define the quantity and schedule of resources provided.

BRIEF DESCRIPTION OF FORM G RESOURCES AVAILABLE FROM NASA

General Purpose Combustion Rig

The general purpose combustion rigs are a pair of identical 2.2-second drop tower rigs that provide a 10" ID by 21" long chamber equipped with 4 windows at the mid plane with 90 degree spacing. Two opposing windows are 4" in diameter, and the other two are 4" x 6". Due to the size of the chamber and the drop frame, only 3 windows are accessible at a time; however the chamber can be rotated to select which three. Four signal/power/igniter wire pairs and 4 type K thermocouple wire pairs are provided in the chamber. Data acquisition and control is via a Tattletale type computer. Power is available at 28, 12, and 5 VDC. A facility for 2 video or 2 movie cameras exists. A gas flow system provides metered fuel flow for gas jet experiments. Maximum operating pressure is 4 Atm, maximum oxygen concentration is 30 %. Utilization of the rigs is generally heavy, so their availability is not guaranteed. In general, they are unavailable in the summer months; time is often available during October through April. The rigs are not available for use away from the Lewis Research Center. Use of the rigs requires approval by NASA LeRC and will require LeRC-led coordination with other users. All changes made to the rig by a user must be fully reversible with limited effort (users will likely be required to return the rig to its original condition upon completion of their testing). Users will have to provide their own optics plate, video cameras, and chamber internals unless their needs match an existing configuration. Users are responsible for obtaining their own safety permit, though their LeRC technical monitor will facilitate this process.

2.2-second Diagnostics Rigs

The combustion diagnostics rigs are nominally designed for utilization in the 2.2-second drop tower facility. Each rig supports a burner platform providing approximately 75 mm of vertical traverse capability. Provided for each burner platform is removable chamber, 41 cm in height with an inside diameter of 19 cm (11.2 liters). The chambers are equipped with 4 optical windows, 75 mm in diameter, spaced at 90 degree intervals. The specific pressure rating of these chambers has not been determined. Each rig is equipped with an optical palette to provide a mounting surface for instrumentation. The surface of each palette has a pattern of 1/4-20 threaded holes on one inch centers, identical to that of laboratory optical breadboards. On rig #1, the chamber is centrally located with a surrounding palette. Rig #2 is configured with the burner platform at one end of the rig, with the palette positioned adjacent. Data acquisition and control is via a 486 microcomputer conforming to the PC104 standard. The present capability provides a variety of A/D inputs and outputs, as well as digital I/O lines. Power is available at 28, 12, and 5 VDC. A facility for 2 video or 2 movie cameras exists. A gas flow system provides metered fuel flow for gas jet experiments. Utilization of the rigs is generally heavy, so their availability is not guaranteed. In general, they are unavailable in the summer months; time is often available during October through April. The rigs are not available for use away from the Lewis Research Center. Use of the rigs requires approval by NASA LeRC and will require LeRC-led coordination with other users. All changes made to the rig by a user must be fully reversible with limited effort (users will likely be required to return the rig to its original condition upon completion of their testing). Users will have to provide their own optics plate, video cameras and chamber internals unless their needs match an existing configuration. Users are responsible for obtaining their own safety permit, though their LeRC technical monitor will facilitate this process.

Computational Microgravity Laboratory

An interdisciplinary computational laboratory is dedicated to providing high-quality analytical and numerical experiment simulations. Supports all microgravity research disciplines. Laboratory has a combination of high-end UNIX workstations with extensive graphics support and an extensive selection of commercial, customized, and experiment-unique software, including most commercial CFD codes. Laboratory staff are available for consultation, analysis, and joint projects. It is recommended that potential lab services be discussed before submission to the NRA. Please call Arnon Chait, (216) 433-3558 or send e-mail to arnon.chait@lerc.nasa.gov

General Purpose Computers

PC and Mac computers for e-mailing, data analysis, report writing, presentation material preparation etc. are available; they may need to be shared with other visitors during your stay at LeRC.

Motion Analysis & Object Tracking System (Tracker)

The analysis of moving objects found in combustion and fluid science experiments has been made easier with the development of the Color Image Processing and Object Tracking System (Tracking System). The Tracking System is a personal computer-based collection of hardware and software that automates the tracking of objects previously recorded on film or videotape.

Typical features are as follows: Tracker is Pentium-Pro-based, uses a single monitor, and supports video devices and/or movie film transport. The input video devices currently supported are a Hi8 tapedeck, an S-VHS tapedeck, a laserdisk (Sony LVR-3000), and laserdisk (Panasonic - rewritable). In addition it also accepts digital images in tif, gif, tga, dxf, eps, img, jpeg, pcx, png, wmf, wpg, PhotoCD, and bmp formats. The tracker PC has a CD-RW drive (CD writer/player which records to a recordable or rewritable CD formats). The Tracker has software to grab sequences of images, digitize, and save them as digital files (tif, etc.) to hard disk, CD-RW drive, jaz drive, zip drive, floppy, or a network drive. Tracker can run on any Windows95 or NT computer, so it can be used to analyze previously saved digital image files.

Tracking methods supported include threshold reduction, template matching, and a spline-based active contour model method. The types of data obtained from Tracker are positions, velocities, area measurements, centroids, and outlines, all as a function of time.

NASA Research Announcement (NRA) Mailing List Update

*This is the form to update information for the NASA Office of Life & Microgravity Sciences & Applications (OLMSA) NRA mailing list. Please fill out **CONTACT INFORMATION** completely. Check only those that apply in **INSTITUTION TYPE** and **PROGRAM AREAS/DISCIPLINES**. **Fold the form, secure with tape (do not staple), and mail it back to the address on the reverse side. Proper postage must be applied.***

Mailing list updates may also be submitted electronically via E-Mail or World Wide Web to the following addresses:

Check one:

- ☐ 1. Please **add** my name to the mailing list.
- ☐ 2. Please **remove** my name from the mailing list (please attach mailing label).
- ☐ 3. Please **change** my current listing (please attach mailing label).
- ☐ 4. Please leave my current listing **unchanged** (please attach mailing label).

Contact Information

If your address has changed or your mailing label is incorrect, please provide COMPLETE contact information.

Prefix: (Mr., Mrs., Ms., Dr., Prof., etc.) ______ **Suffix: (M.D., Ph.D., Jr., III, etc.)** ______

Name, First: ______ **Last:** ______

Position Title: ______

Mail Code, Loc: ______

Office, Dept, Div: ______

______

Univ./Agency/Ctr, ______

______

Street or PO Box: ______

City: ______ **State:** ______

Zip Code: ______ **Country:** ______

Telephone No: ______ **Fax No:** ______

Internet/E-Mail: ______

Institution Type

(check all that apply)

- ☐ 1. College or University
- ☐ 2. Minority College or University
- ☐ 3. Minority Business
- ☐ 4. NASA Center
- ☐ 5. Other Government Agency
- ☐ 6. Nonprofit Corporation
- ☐ 7. Small Business
- ☐ 8. Private Industry
- ☐ 9. Foreign Addressee

Program Areas/Disciplines

(check main area of interest)

- ☐ **1. Life Sciences**
  - ☐ A. Advanced Life Support
  - ☐ B. Advanced Technology Development
  - ☐ C. Data Analysis
  - ☐ D. Environmental Health
  - ☐ E. Space Biology
  - ☐ F. Space Human Factors
  - ☐ G. Space Physiology & Countermeasures
  - ☐ H. Space Radiation Health
- ☐ **2. Microgravity Sciences**
  - ☐ A. Biotechnology
  - ☐ B. Combustion Science
  - ☐ C. Fluid Physics
  - ☐ D. Fundamental Physics
  - ☐ E. Materials Science

☐ Please send me notifications of announcements via E-Mail only.

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